Instruments

THE MAGAZINE OF MEASUREMENT
INSPECTION · TESTING · CONTROL

cluding the

JOURNAL OF THE INSTRUMENT SOCIETY OF AMERICA

d the

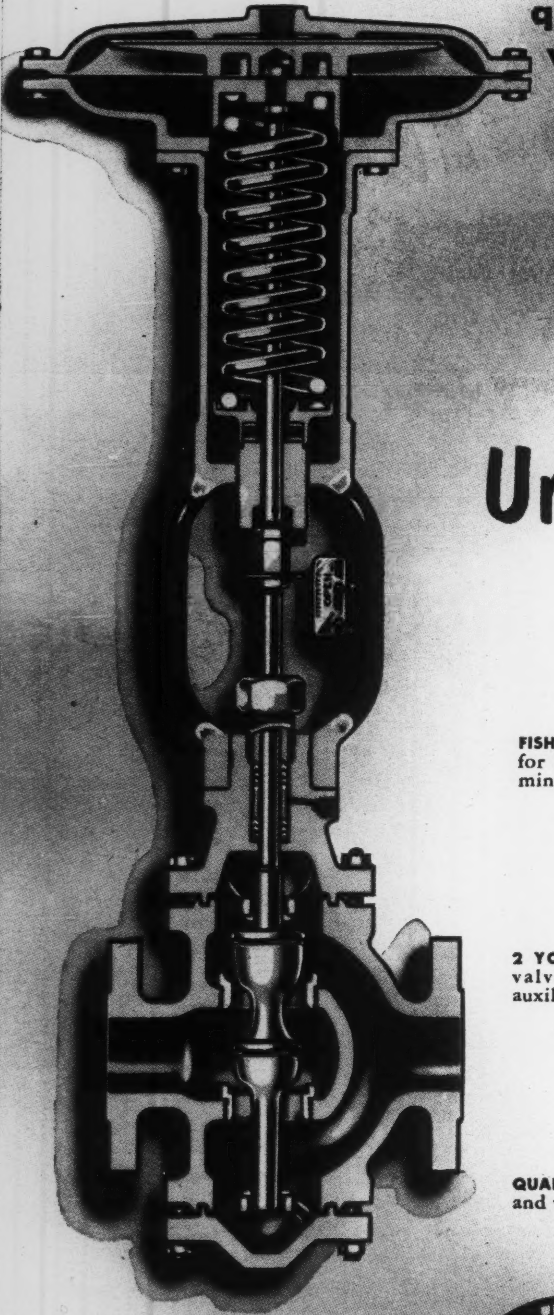
JOURNAL OF THE SOUTHERN CALIFORNIA METER ASSOCIATION

n this issue . . .

- Valve Control of Liquid Flow
- Capacitor-charging Circuits
- Moisture Measurement
- pH Measurement
- Process Control by Servomechanism
- Instrument Electronics
- Thermocouple Checking
- Improved Luft-type Analyzer
- Resistance Thermometry
- 78 New Instruments
- 108 New Bulletins

Vol. 25 No. 5
MAY • 1952

Part of the panelboards for a natural-gas installation of Consolidated Edison Company of New York, at Astoria, Long Island.
(Photo courtesy Falstrom Company)



Exclusive features of design plu quality controlled materials and workmanship are the reasons

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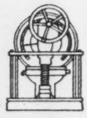
Diaphragm Motor Valves are Universally Preferred



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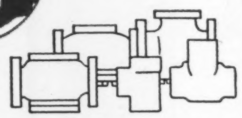
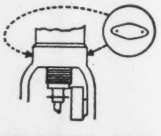
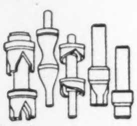


VARIETY OF BODY TYPES and materials—iron, steel, bronze, alloys, single and double seated, angle and globe.



2 YOKE MOUNTING PADS for valve positioner and other auxiliary equipment.



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QUALITY CONTROLLED materials and workmanship.

WALL SECTIONS conform with ASA fittings code.

VERSATILE! ECONOMICAL!

Teflon V-Ring Packing, requiring no lubrication, is standard on all Fisher Diaphragm Motor Valves

Dual Teflon packing also available. 2 sets of packing separated with bleed area where purge zone is desired. Positively prevents outbound leakage—or inbound leakage under vacuum service. For dangerous toxic, corrosive, etc. applications.

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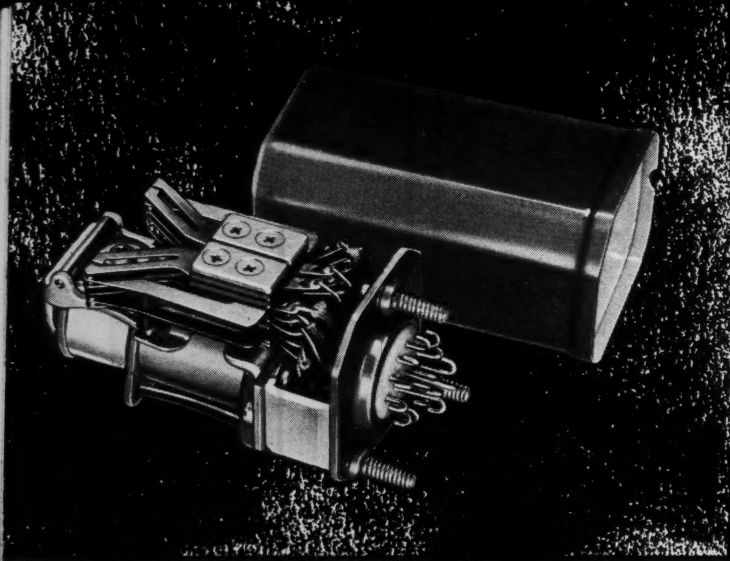
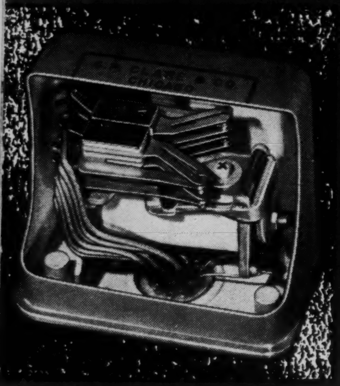
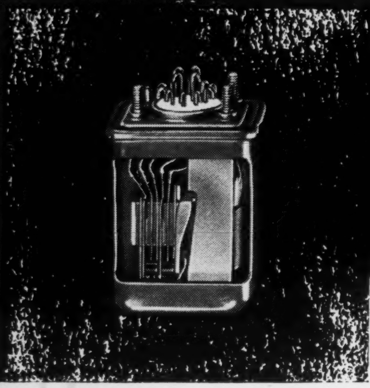


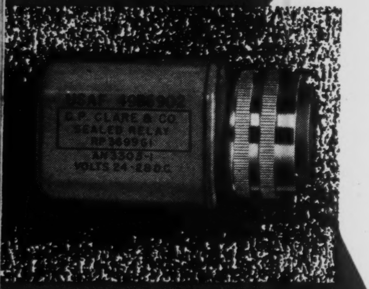
▲ Clare Type "J" [illegible] relay before sealing in enclosure.



▲ Another type of enclosure (cut-away) shows compactness of assembly.



Cutaway view of Clare Type "K" hermetically sealed relay.



▲ "AN" approved Clare hermetically sealed relay with "AN" plug connector.

Connection diagrams are clearly and permanently imprinted on enclosures by silk screen process. ▼

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Address C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials Ltd., Toronto 13.

CLARE RELAYS

First in the Industrial Field

How CROSBY's BALANCED AREA DESIGN eliminates back pressure effects

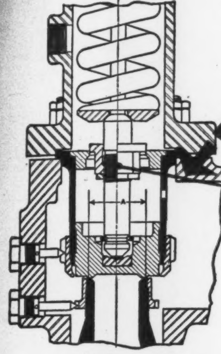


Fig. I

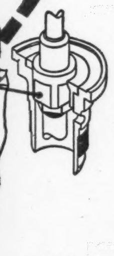


Fig. 2

When a standard relief valve on gas or vapor service is installed, where back pressure exists, one of two undesirable effects will occur:

Constant Back Pressure — The back pressure acts on part of the upper and the overhanging part of the lower surface of the disc, cancelling out the back pressure force. There remains, however, a force acting on the top portion of disc (area A) which increases the spring load and causes the valve to pop "heavy."

Variable Back Pressure can not be compensated for by spring adjustments. When one or more valves discharge into a common flare header, variable back pressure is placed on the remaining closed valves. This can create a hazardous condition on remaining closed valves, by adding to the spring force. The valve then is prevented from opening until pressure has risen far above the vessel design limit.

[redacted] is a simple, foolproof method of nullifying these undesirable effects (see Figure 1 above).

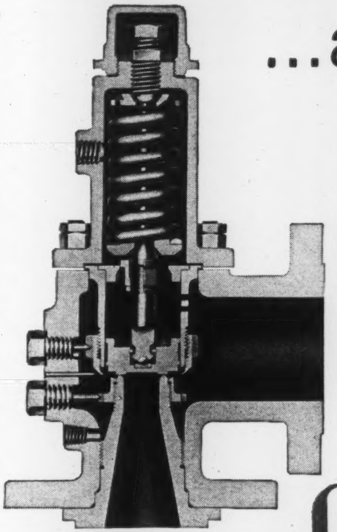
Operation — Crosby achieves *Stable Popping Pressure* by the addition of a piston affixed to the spindle, of area proportioned to equal the unbalanced area of the disc (area A in Fig. 1). Back pressure introduced through the port in the guide then acts on two equal areas in opposite directions, and cancels itself out, neither aiding nor opposing the spring.

To assure full lift and stability, a vent system (see sectional view of piston, Fig. 2) is employed. When the valve is open, the flats on the piston will vent any accumulated back pressure that would tend to close the valve. The adjustment and operating characteristics are similar to the conventional valve. The actual flow into the bonnet is relatively low and can be vented to atmosphere, or through a properly sized discharge header.

Extensive, trouble-free use in the field has proved the success of this Crosby Balanced Area Design.

Here's the [redacted] RELIEF VALVE which eliminates back pressure effects

...and reduces costs!



CROSBY RELIEF VALVE
Style JO-BP
with BALANCED AREA DESIGN
for the elimination
of Back Pressure Effects.

Proved ECONOMY!

On the many installations where Crosby JO-BP Valves have been in operation, refineries report sizable savings in piping costs. The reason—smaller discharge lines made possible by higher back pressure. Since Crosby JO-BP Relief Valves will handle back pressure surges ranging up to 90% of inlet pressure, smaller diameter discharge pipe carries the same amount over the same distance that formerly required much larger pipe.

Proved PROTECTION!

On-the-job performance of Crosby JO-BP Relief Valves proves that you can depend on the vented Balanced Area Design to operate on the set pressure. Thus you are assured of a *Stable Popping Point*. What's more, a full lift is obtained over the normal range of back pressures. The Crosby JO-BP operates with an unrestricted nozzle, follows standard nozzle flow equations for above or below critical ratio as the case may be. With its vented Balanced Area Design, the Crosby JO-BP provides a foolproof, time-tested method of eliminating back pressure effects.

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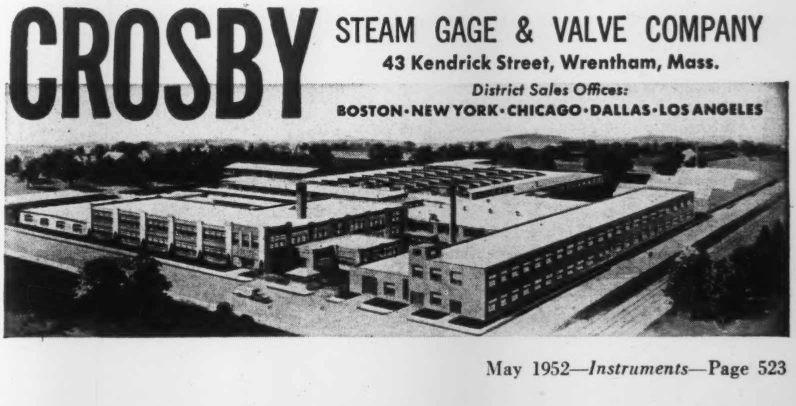

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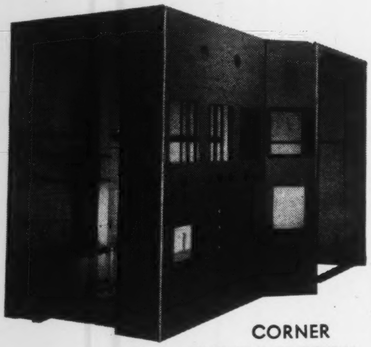

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Vol. 25 MAY, 1952 No. 5

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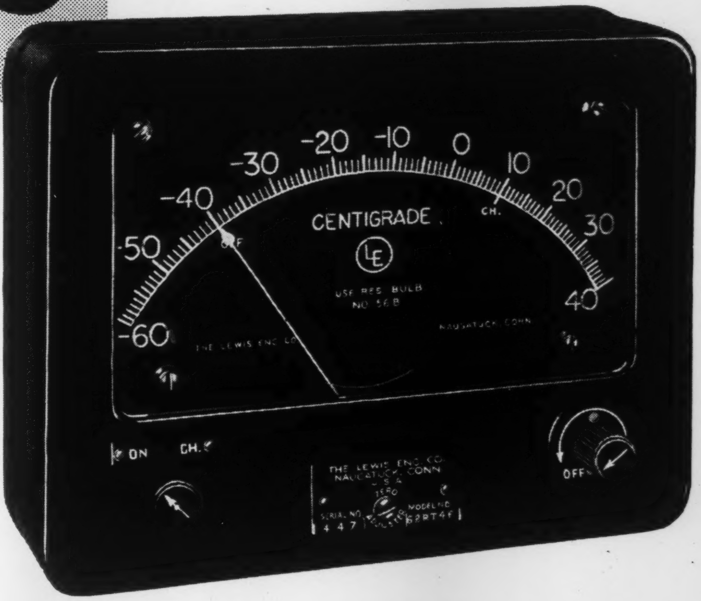
LEWIS

RESISTANCE THERMOMETER AND ACCESSORIES

The Model 62 RT4F Resistance Thermometer is a sturdy, easy to read instrument with a six inch hand drawn scale. It is suitable for use in moving vehicles, is excellent for flight testing or for permanent panel installations. Operated by an ordinary dry cell and calibrated to standard "AN" bulb curves, this instrument is ideal for use with any of the resistance bulbs illustrated below. Other ranges available in °C or °F.


-60
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CENTIGRADE
USE RES. BULB NO. 56B
THE LEWIS ENG CO
NAUGATUCK CONN
ON
CH.
OFF
THE LEWIS ENG. CO.
NAUGATUCK, CONN.
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MODEL NO. 62RT4F

ACCESSORIES — RESISTANCE BULBS AND SWITCHES

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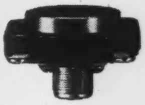

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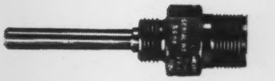
2" SIZE TO 4 POINTS



THREADED "AN" TYPE

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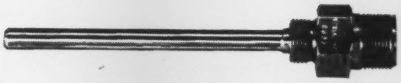
3" SIZE TO 20 POINTS



THREADED "AN" TYPE

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4" SIZE TO 28 POINTS

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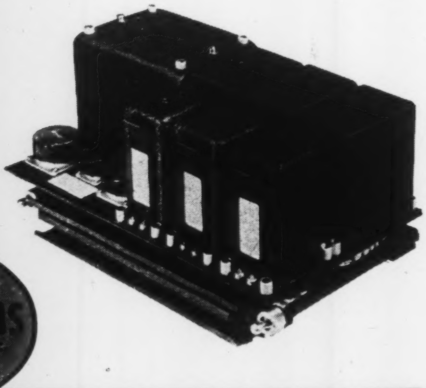

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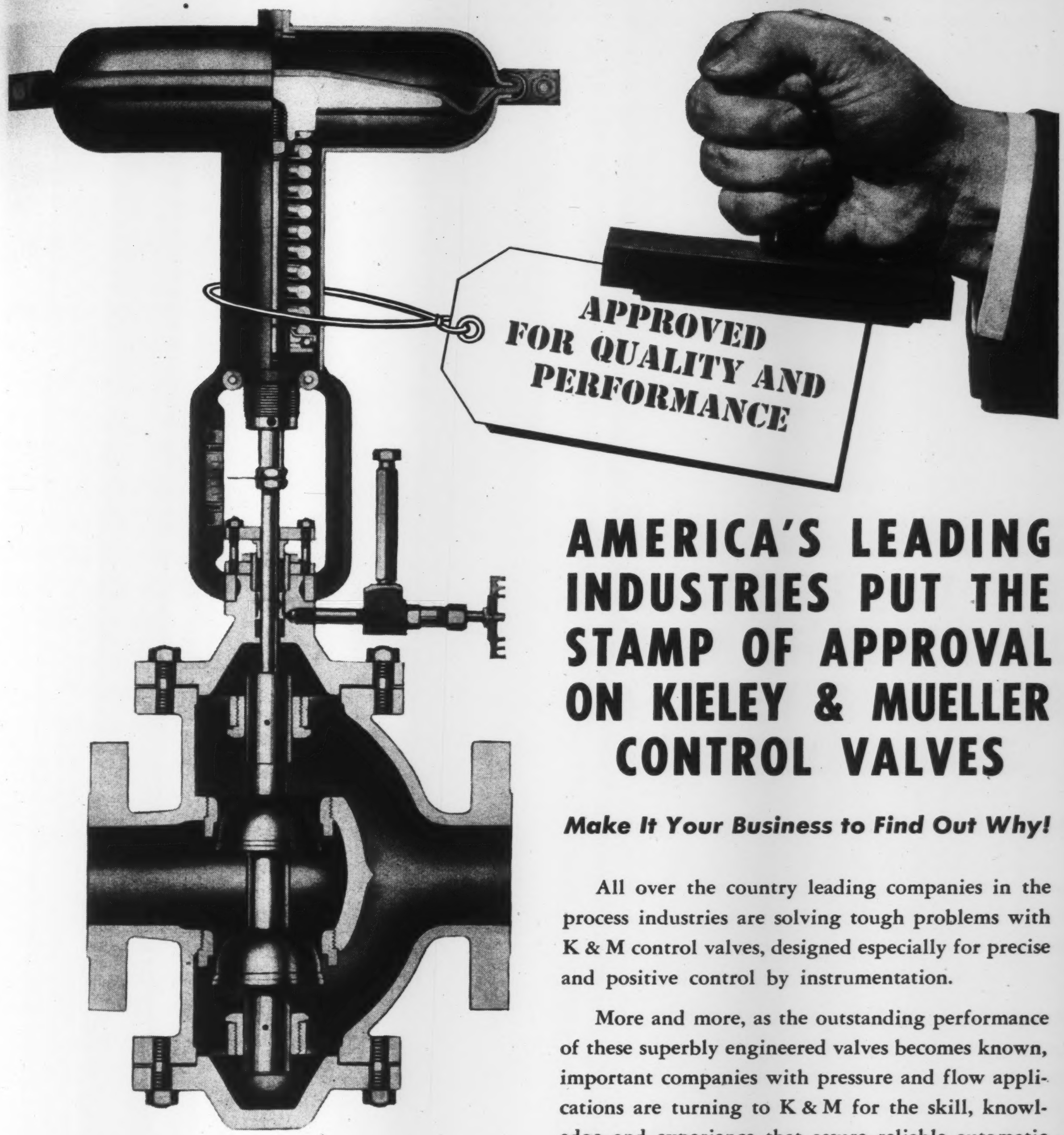

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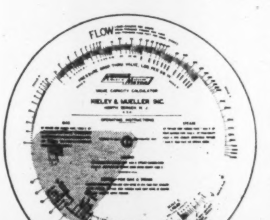

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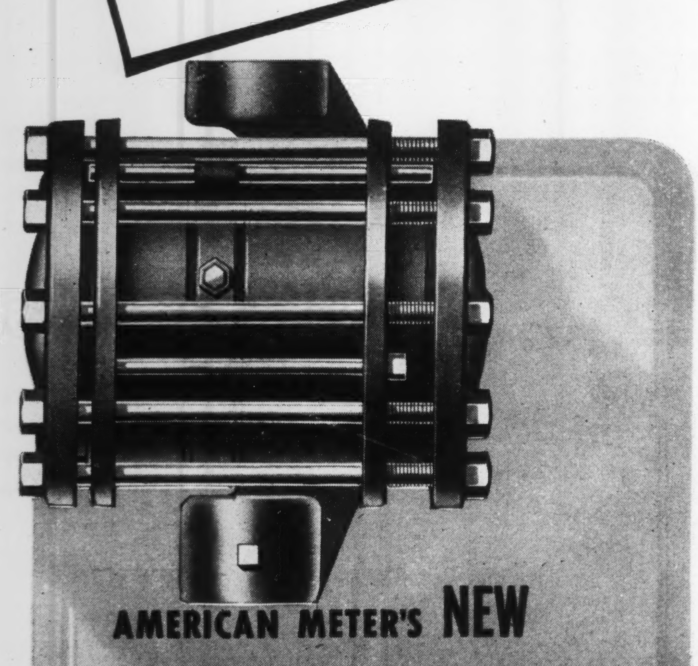

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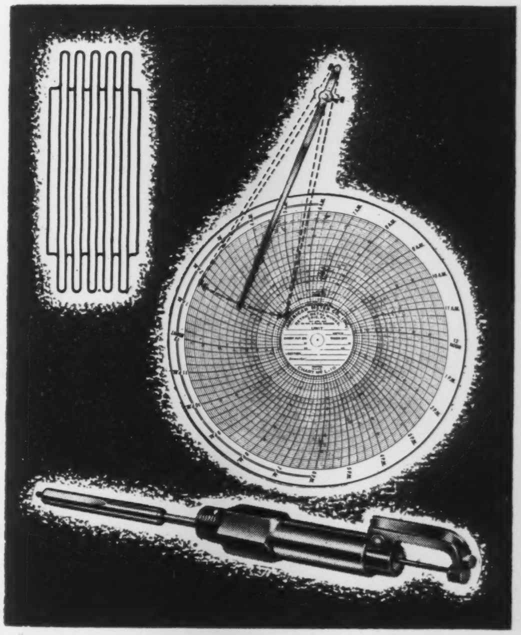

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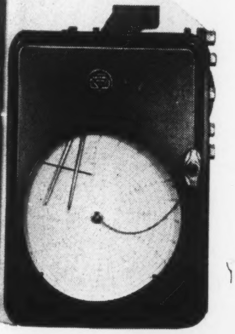

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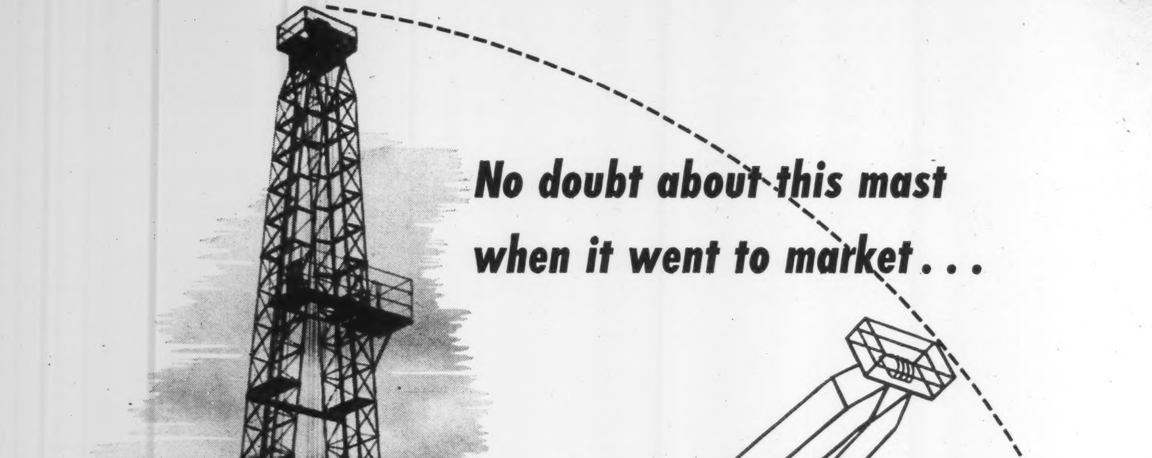
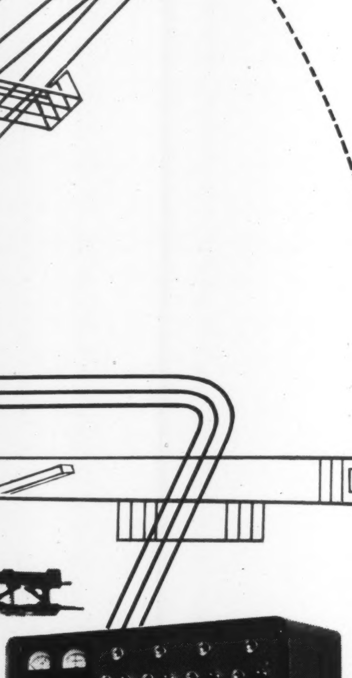


No doubt about this mast when it went to market . . .



Raising a 35-ton mast of structural steel from horizontal to full vertical position is a problem in itself. Being certain that, once raised, the 143-ft.-high structure is able to support the tremendous weight of a string of drill pipe is still another problem. Add to these requirements the ability of the mast to be skidded across oil-field terrain, and you have a structural engineer's nightmare.

IDECO, in designing their "Full-View" drilling mast, had to know the complete stress and strain story of this structure. By using Consolidated Dynamic Recording Equipment—strain gages, bridge balance, and recording oscillograph—a complete stress analysis was made while the mast was being raised or lowered, or was standing vertically under a simulated pipe load. Thus the engineers removed any trace of doubt from the mast design. Consolidated's broad experience in applying instrumentation to design and production problems may be profitable to your business.

Consolidated Engineering
CORPORATION
300 No. Sierra Madre Villa, Pasadena 8, California

Analytical Instruments for Science and Industry

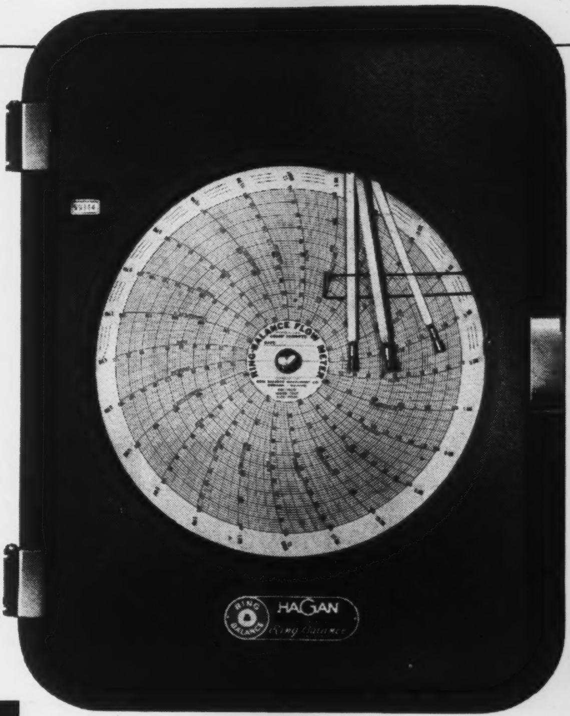
Recording Oscillograph

The 5-114 Recording Oscillograph records up to 18 simultaneous reactions as brief as one-hundred-millionth of a second. Produces clear, permanent records for future analysis. Applications vary from the field of medicine to rocket-propelled planes. Write for Bulletin 1500B.

HAGAN Compensated Ring Balance Meters

provide *accurate, automatic* compensation

- for *temperature*
- for *pressure* or
- for *pressure and temperature*



When you measure flow of liquids or gases, and pressure and temperature variations occur, there are two ways to correct meter readings — one by expensive and laborious clerical calculations, the other, by using the Hagan Compensated Ring Balance Meter in the first place. This Hagan Compensated Meter corrects *automatically* for variations in pressure, temperature, or pressure and temperature, and makes a chart record of both the corrected and the uncorrected flow. The built-in integrator totalizes the corrected flow automatically.

Dependable Hagan Ring Balance Meters are simple, ruggedly built, and designed for years of trouble-free service. Some features of Hagan Ring Balance Meters include:

- **Mercury level not critical**
- **Ease of dead-weight calibration**
- **No stuffing boxes or pressure-tight bearings**
- **High sensitivity at low flow rates**
- **Adjustable, full-scale range**

Whatever your metering problems, our engineers are at your service. For full information, phone, wire, or clip the coupon.

HAGAN CORPORATION

RING BALANCE FLOW AND PRESSURE INSTRUMENTS
THRUSTORQ FORCE MEASURING DEVICES
BOILER COMBUSTION CONTROL SYSTEMS
METALLURGICAL FURNACE CONTROL SYSTEMS

Hagan Corporation
Hagan Building
Pittsburgh 30, Pennsylvania

Please send me further information on Hagan Ring Balance Meters. I am particularly interested in ....

....

NAME ....

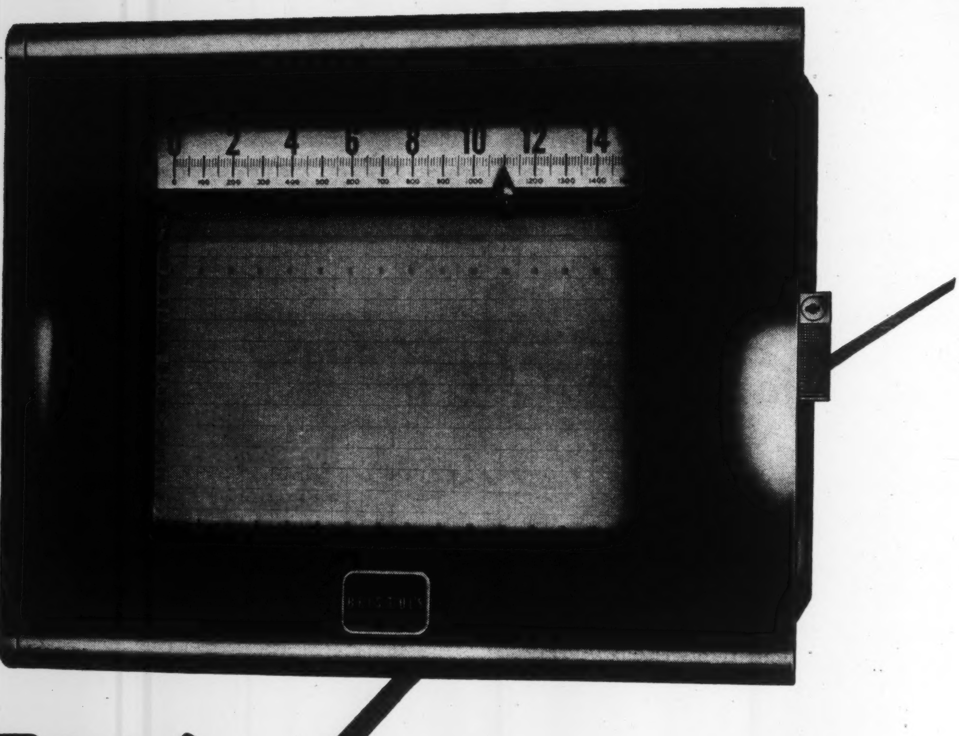
POSITION ....

COMPANY ....

STREET AND NUMBER ....

CITY .... ZONE .... STATE ....

I-5



CHECK the Versatility

of the BRISTOL DYNAMASTER

Continuous-balancing electronic instruments

Dynamasters can be used with "sensing elements" like these:

Resistance thermometers, strain gauges, conductivity cells, thermocouple or radiation pyrometers, tachometer magnetos, pH amplifiers, gas analyzers, X-ray and radiation thickness gauges, photoelectric cells, spectrometers, gas detectors, titrometers, and others

To measure, record and control quantities like these:

Temperature, pressure, volts, amperes, watts, thickness, liquid, flow, liquid level, load, weight, strain, torque, position, conductivity, ionization, rpm, illumination, density, and many others

BRISTOL

The dependable Guidepost of Industry

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

..and Double Check THESE FEATURES:

- All types of electric and air-operated controllers offered
- Continuous-balancing electronic circuit responds instantly to minute changes
- Simple design assures trouble-free operation
- Little or no maintenance
- Circular or strip-chart models, single or multiple recorders
- Electronic component uses vacuum tubes available at any radio supply house
- Full-scale pen travel in 2/3, 3, or 7 seconds
- Wide variety of chart speeds
- Components interchangeable on all Dynamaster models, easily serviced or replaced
- Exceptionally unaffected by stray currents (1000 to 1 discrimination)
- Available in bridges or potentiometers
- Practically immune to shock or vibration

AND THAT'S NOT ALL! *For more details, use the coupon to send for Catalog No. P1245.*

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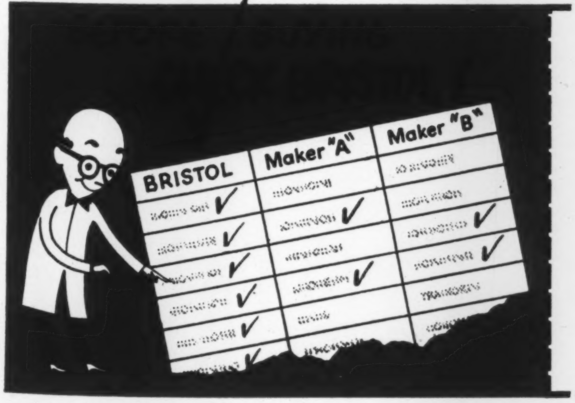

THE BRISTOL COMPANY
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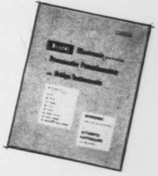

Please send catalog giving details of Dynamaster performance to:

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COMPANY______________________________________

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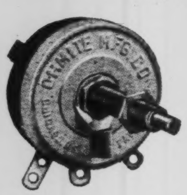
What Special Feature do you need in a RHEOSTAT?

OHMITE CAN SUPPLY IT!

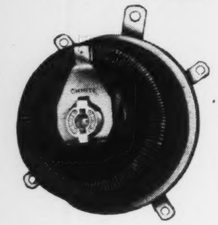
In addition to standard rheostats, Ohmite offers rheostats with a wide variety of *special features*. All have the distinctive Ohmite design features: smoothly gliding metal-graphite brush; all-ceramic construction; insulated shaft and mounting; windings permanently locked in place by vitreous enamel.

BUSHINGS FOR SPECIAL PANEL THICKNESS



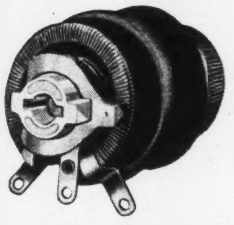
Extra-long bushings and shafts allow mounting on panels up to 2 inches in thickness. Seven bushing lengths are available, from ¼ to 2⅛ inches.

360° WINDING



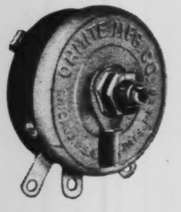
Two small models available with continuous circular core and endless winding. Unlimited rotation of shaft and contact arm. Taps supplied at any desired angle on windings.

DEAD LUG OFF POSITION



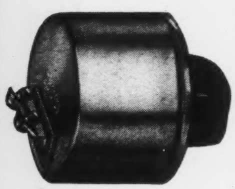
Opens the circuit at the high or low resistance position as the contact passes on to the lug, which is disconnected from the winding. Recommended for light duty.

SCREW DRIVER SLOT SHAFT



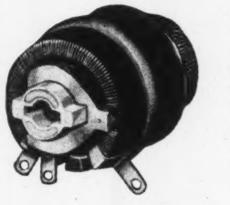
Where infrequent adjustments are needed, shaft ends can be slotted for operation with a screwdriver. Tampering with the shaft setting is thus minimized.

SEALED, ENCLOSED CAGES



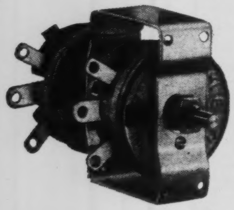
Compact, corrosion-resisting metal enclosure, permanently sealed by a double seam, protects the unit completely. Available with rheostat Models H and J.

SNAP-ACTION OFF POSITION



Opens the rheostat circuit at the high or low resistance position. The circuit is opened as the brush snaps into an insulated notch next to the lug, providing indexing.

TANDEM ASSEMBLIES

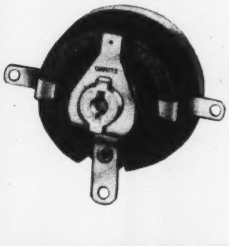


Ohmite rheostats can be mounted two or more in tandem, for simultaneous operation of several circuits. Universal joints provide smooth, positive mechanical action.

TOGGLE SWITCH

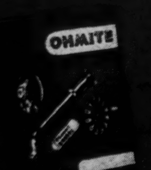
Toggle switch is operated with a positive snap by the movement of the contact arm. Opens the rheostat circuit or switches an independent circuit. Available for all models.

LESS THAN STANDARD ROTATION



Rheostats can be supplied with winding space and angle of rotation less than standard. Rheostats can also be supplied with fixed or adjustable stops.

OHMITE MANUFACTURING COMPANY
4886 Flournoy Street, Chicago 44, Illinois



Write on Company Letterhead for Catalog and Engineering Manual No. 40.

Be Right with
OHMITE
RHEOSTATS • RESISTORS • TAP SWITCHES

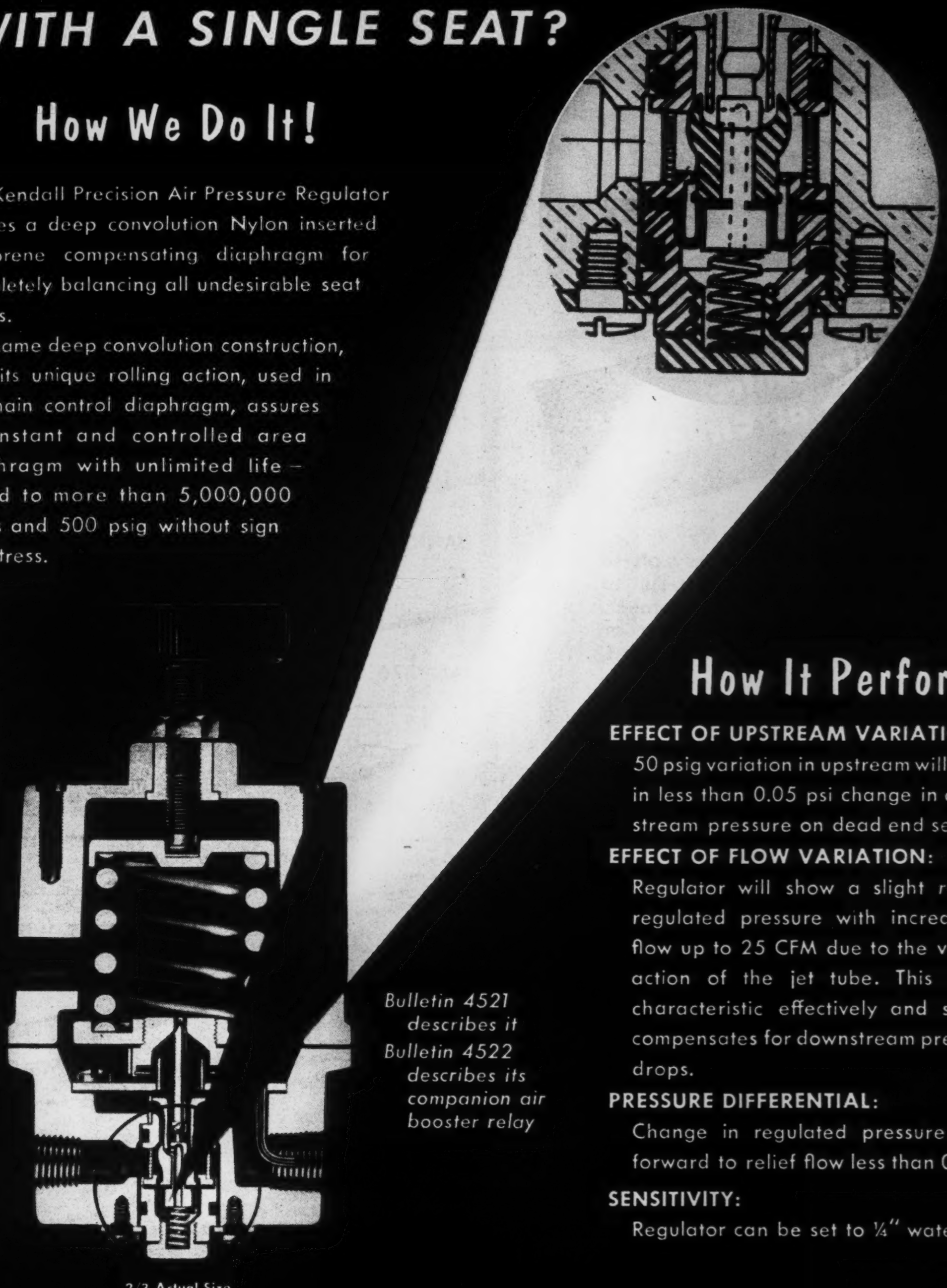
Engineered Air Regulation

EVER SEE A BALANCED VALVE *WITH A SINGLE SEAT?*

How We Do It!

The Kendall Precision Air Pressure Regulator utilizes a deep convolution Nylon inserted Neoprene compensating diaphragm for completely balancing all undesirable seat forces.

This same deep convolution construction, with its unique rolling action, used in the main control diaphragm, assures a constant and controlled area diaphragm with unlimited life – tested to more than 5,000,000 cycles and 500 psig without sign of distress.



2/3 Actual Size

Bulletin 4521 describes it

Bulletin 4522 describes its companion air booster relay

How It Performs!

EFFECT OF UPSTREAM VARIATION:

50 psig variation in upstream will result in less than 0.05 psi change in downstream pressure on dead end service.

EFFECT OF FLOW VARIATION:

Regulator will show a slight *rise* in regulated pressure with increase in flow up to 25 CFM due to the venturi action of the jet tube. This rising characteristic effectively and simply compensates for downstream pressure drops.

PRESSURE DIFFERENTIAL:

Change in regulated pressure from forward to relief flow less than 0.1 psi.

SENSITIVITY:

Regulator can be set to ¼" water.

KENDALL CONTROLS CORPORATION

144 MOODY STREET WALTHAM 54, MASS.

*Quality Controlled** TO THE HIGHEST STANDARDS OF THE INDUSTRY

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WIRES and CABLES

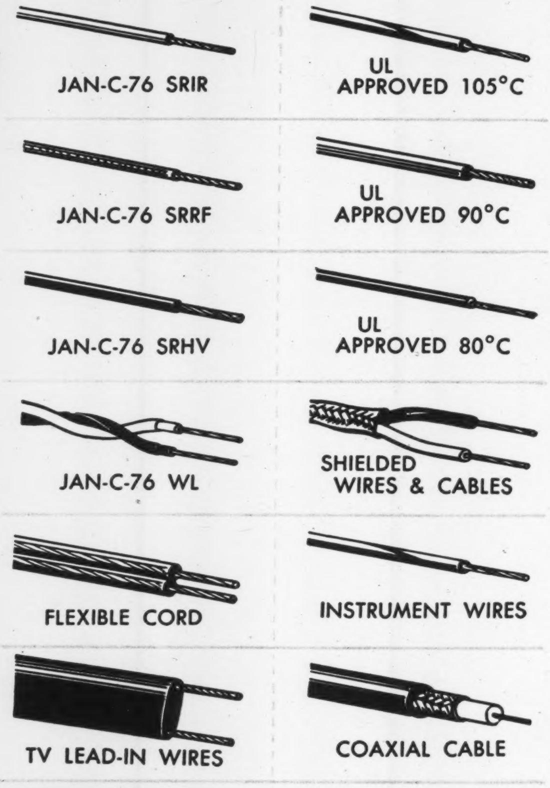
***Quality Control works 2 ways at CHESTER**

It's a fact and here's why! First, Chester quality control engineers certify every phase of manufacture from raw material to finished product packed for shipment. No detail is too small or unimportant to merit their full attention. Second, quality in turn governs production — not a single foot of Chester wire or cable is ever "hurried through" to meet a shipping date or heavy schedule. Extra shifts, not faster production is the method used to break bottlenecks at Chester.

This two way quality control is just one of many important reasons why electrical and electronic men, in increasing number, specify Chester wire and cable for an extra measure of reliability. Why not check your requirements with Chester today.

FOR EVERY APPLICATION —

JAN-C-76 Wires • 80°-90°-105°C Hook-Up Wire • Shielded Wire and Cable Flexible Cords • Coaxial Cable • Television Lead-In Cable • Gas Tube High Tension Cable • Oil Burner Ignition Cable • Blasting Wire • Thermostat Cable • Bell and Office Wire • TW Building and Fixture Wire


JAN-C-76 SRIR
UL APPROVED 105°C
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JAN-C-76 WL
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CHESTER CABLE CORP.
CHESTER, NEW YORK

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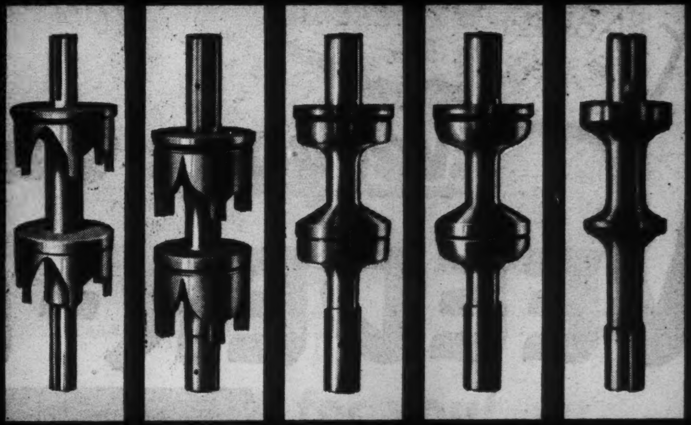
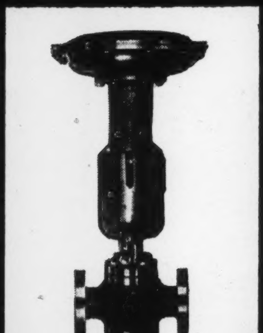
Rely on Plasticord and Plasticote — write for the new Catalog today

MANUFACTURERS OF QUALITY WIRE AND CABLE FOR EVERY ELECTRICAL AND ELECTRONIC REQUIREMENT

WIDE SELECTION . . .



for any valve application



Discs for the Honeywell Series 700 Valve include single and double-seated V-ported and contoured types, each with either linear or equal-percentage characteristics, plus a flat disc for on-off control . . . all ground and polished . . . all designed to retain characteristics under severe service. The Honeywell Series 700 Valve comes in a full range of styles and sizes . . . has *all* the features you look for in a fine valve. Write today for your copy of Bulletin 700-2. MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division,* 1908 Windrim Avenue, Philadelphia 44, Pa.

MINNEAPOLIS
Honeywell
VALVE PRODUCTS

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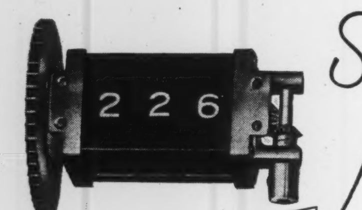
First in Controls

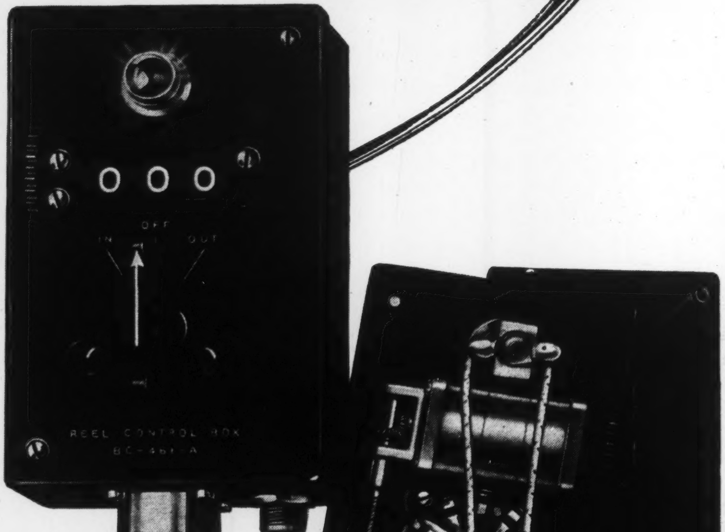


Added Evidence that———

Small Component...
or Complete Unit...
You* can count on
getting whatever
You* need—

Everyone Can Count on

VEEDER-ROOT



This REEL CONTROL BOX, complete with its *built-in* counting mechanism, indicates the number of feet of antenna reeled in and out of certain types of military aircraft. Manufactured completely by Veeder-Root, including outside bakelite cover and box, this unit shows another imaginative application of the universal language of direct-reading *Count*rol.

Now if you, *in any of your defense work,** have a counting problem, then you can count on Veeder-Root to help you in every possible way.

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Montreal 2, Canada • Dundee, Scotland
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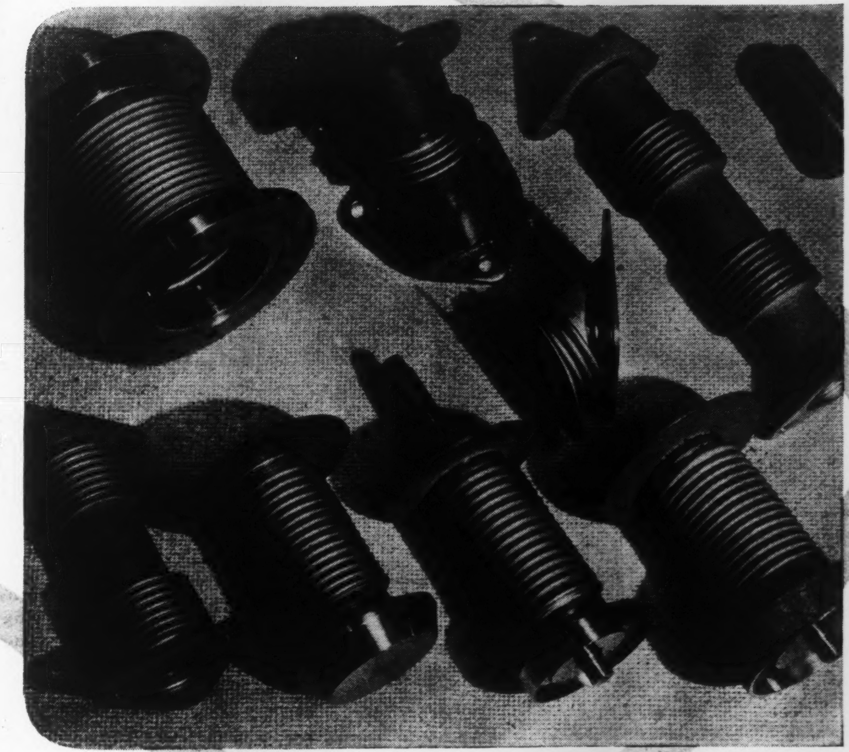
"Counts Everything on Earth"

STAINLESS STEEL BELLOWS ASSEMBLIES



...Designed for YOU to SAVE for you!

● Whatever your requirements for stainless steel bellows assemblies may be, you can be assured of getting *exactly* what you need from Fulton Sylphon or Bridgeport Thermostat.

We design and engineer assemblies to do specific jobs. For example—for use where there's a design problem involving control of temperature or pressure . . . opening and closing of valves, dampers, etc. . . . absorbing expansion . . . providing packless construction . . . for more uses throughout industry.

And add *these* advantages that help make savings for you: Half-a-century of experience in this specialized field . . . skilled personnel . . . complete production facilities . . . ability to produce in any volume. All combine to relieve you of production problems and worries, help save you time and money.

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TEMPERATURE CONTROLS

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Knoxville 4, Tenn.

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CONTROLS COMPANY

BRIDGEPORT THERMOSTAT
DIVISION
Bridgeport 1, Conn.

BELLOWS ASSEMBLIES • BELLOWS DEVICES

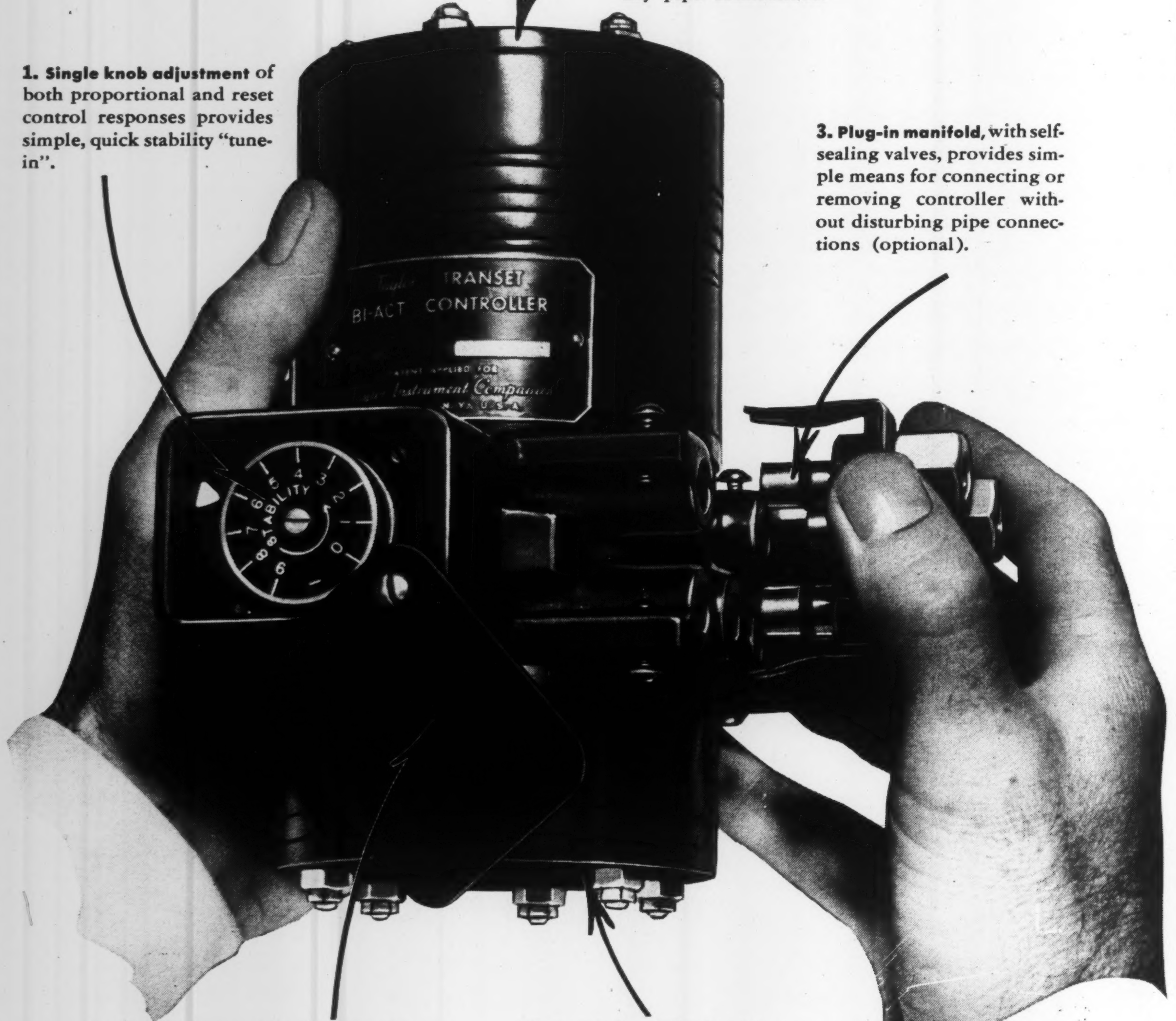
Two ways the new Taylor

1. BY THESE DISTINCTIVE FEATURES:

2. Change from direct to reverse action is made easily, quickly by rotating top plate without disturbing any pipe connections.

1. Single knob adjustment of both proportional and reset control responses provides simple, quick stability "tune-in".

3. Plug-in manifold, with self-sealing valves, provides simple means for connecting or removing controller without disturbing pipe connections (optional).

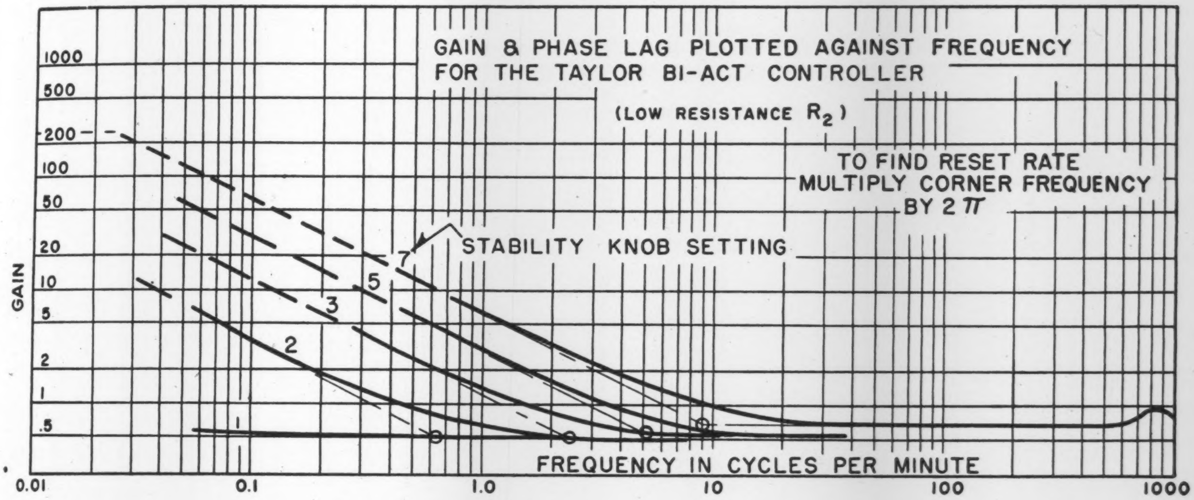

Taylor TRANSET
BI-ACT CONTROLLER
PATENT APPLIED FOR
Taylor Instrument Companies
N.Y. U.S.A.
STABILITY
8 7 6 5 4 3 2 1 0

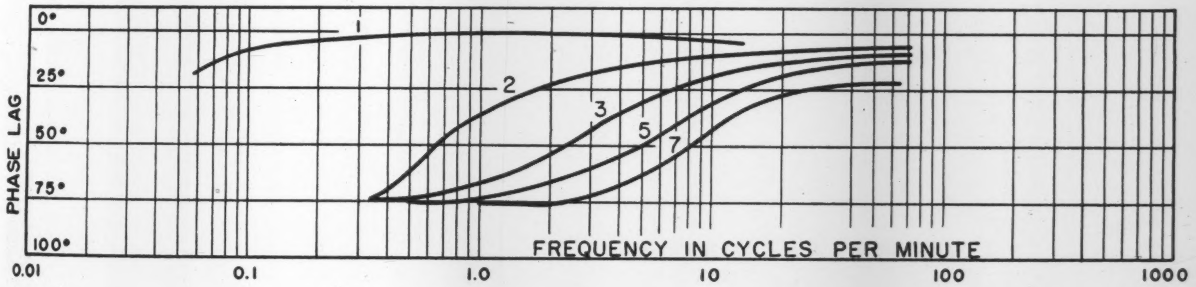
5. Cover plate protects control knob from elements, damage, and tampering.

4. Integral cut-off relay on every BI-ACT unit permits panel or field mounting.

to describe Bi-Act* Controller

2. BY FREQUENCY RESPONSE ANALYSIS:





* Trade-Mark

The above graphs describe the BI-ACT Controller designed for use in industrial processes with short time lags such as close-coupled liquid flow, fast pressure and comparable temperature problems.

Send for Bulletin 98097 describing the TRANSET Control System, or any of the following papers: **"Frequency Response Analysis"** . . . **"Frequency Response Data on BI-ACT Controllers"**

Taylor Instrument Companies, Rochester, N. Y., and Toronto, Canada. *Instruments for indicating, recording and controlling temperature, pressure, flow, liquid level, speed, density, load and humidity.*

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MEAN
ACCURACY FIRST
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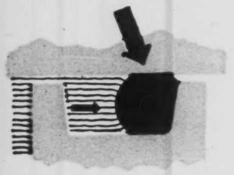
Cutaway view showing O-rings in Pesco hydraulic pump for aircraft and industrial applications.

Simplified Leakproof Seals

WITH PARKER O-RINGS

THIS IS IT



Cross section drawing of O-ring in groove, sealing under pressure.

PARKER synthetic rubber O-rings are simple to use, simple to replace. They require no complicated product design . . . a simple groove is all that is needed. Economical in first cost, they provide perfect, leakproof sealing with economy of weight and space . . . can be used in moving and non-moving applications.

PARKER is the one source for all standard O-rings to meet specifications covering fuel, hydraulic and engine oil services . . . and for special service O-rings of tested and approved compounds. Your Parker O-ring distributor listed at the right will give you Catalog 5100 . . . or write direct to The PARKER Appliance Company, 17325 Euclid Avenue, Cleveland 12, Ohio.

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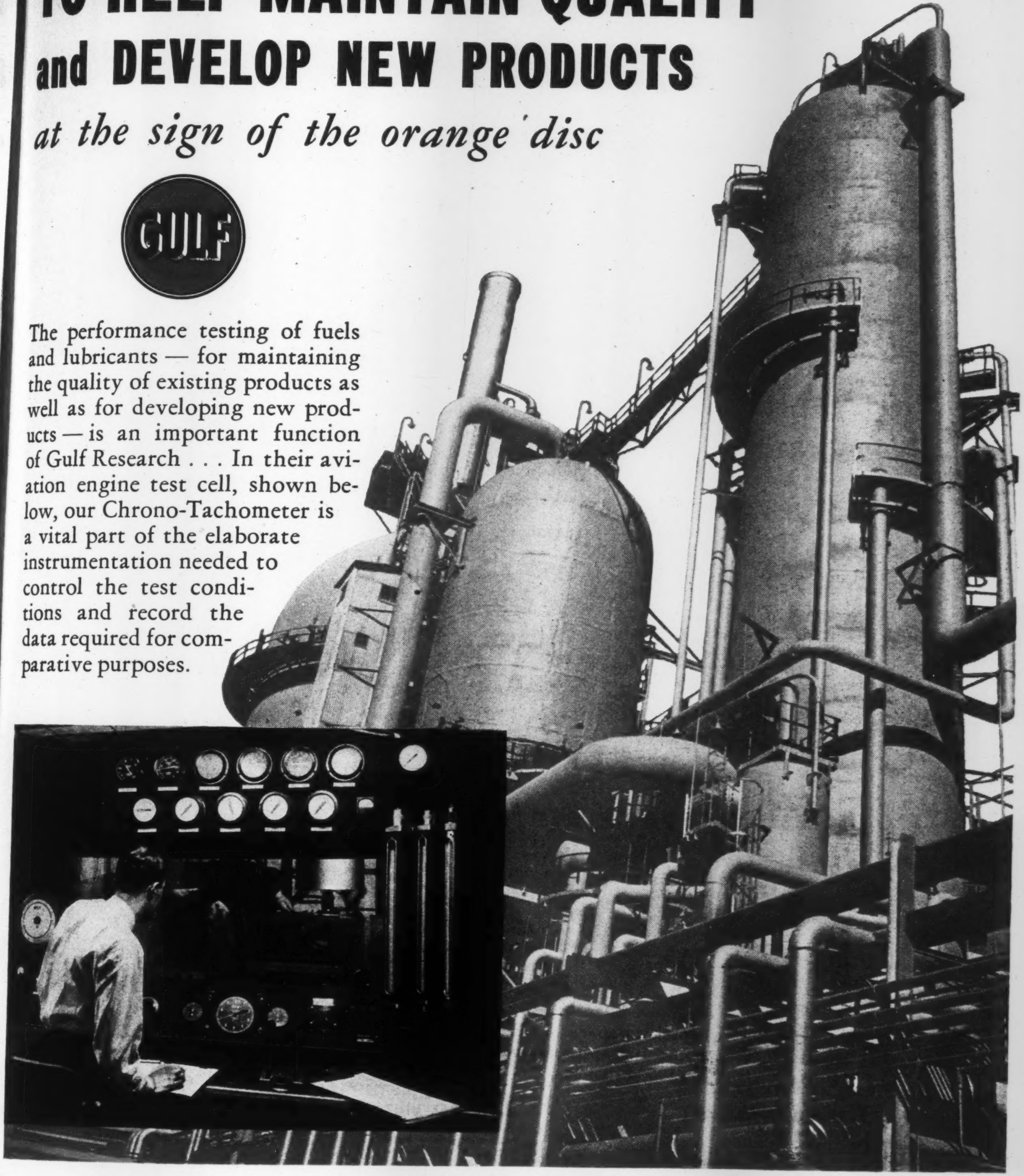

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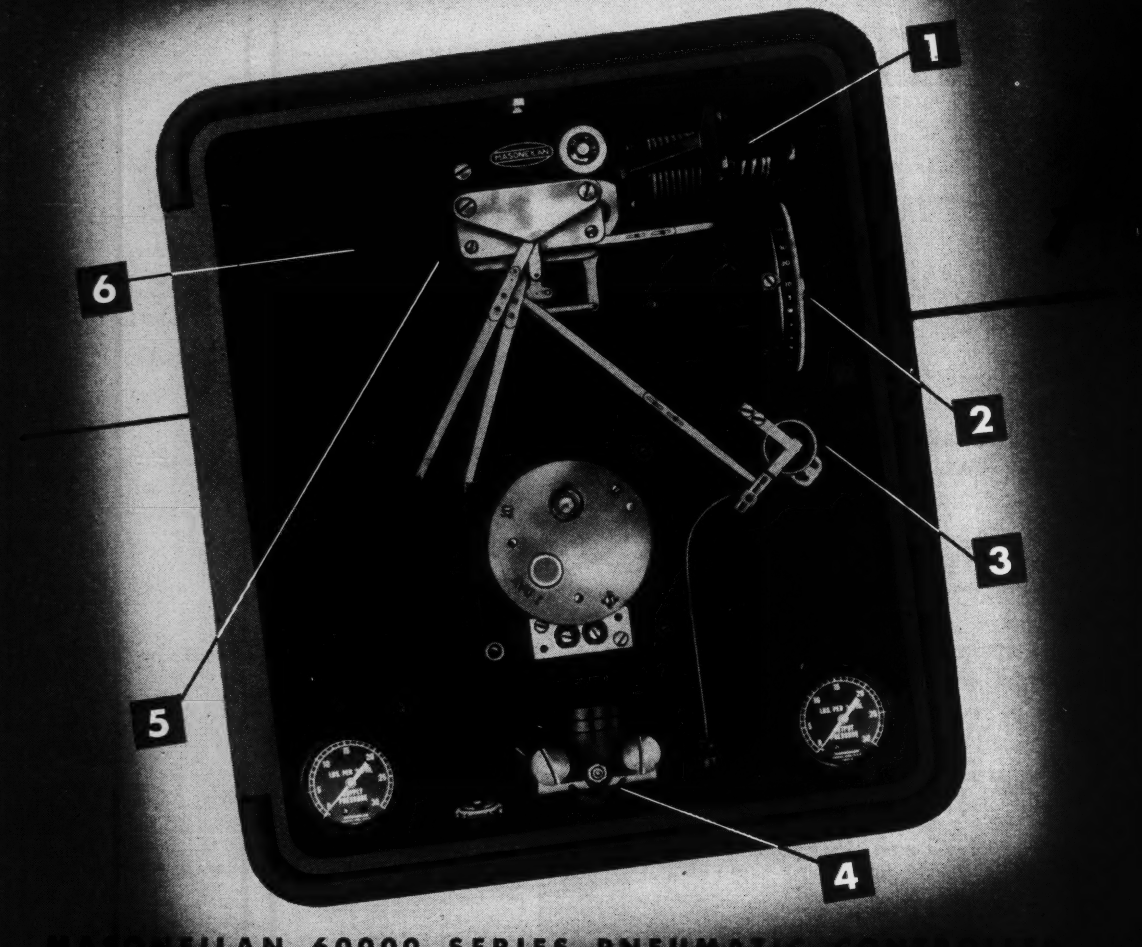
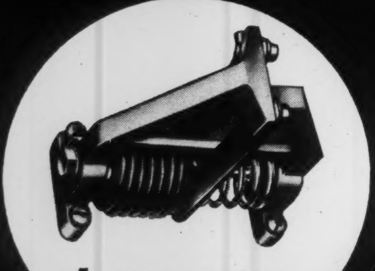
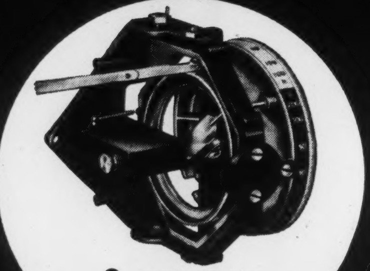


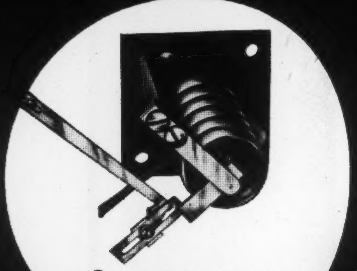
MASONEILAN 60000 SERIES PNEUMATIC CONTROLLER



1. PROPORTIONAL UNIT
interchangeable with proportional-reset unit.



2. GIMBAL UNIT
combines primary and feed-back motions — basic in all controllers.



3. PRIMARY ELEMENT
helical or spiral bourdon, or bellows as required.

A HIGH CQ PRODUCT

MASONEILAN

The New Masoneilan "6-in-1" Controller
IS SIMPLE AS ABC

One Setting of basic "6-in-1" controller

selects on-off, proportional, or differential-gap control; direct or reverse action; proportional band or differential-gap setting.

Easy to Set, Adjust, Test and Service —

all settings made without removing chart; all subassemblies complete and directly accessible; all air passages manifolded; four-position transfer switch in manual control subpanel.

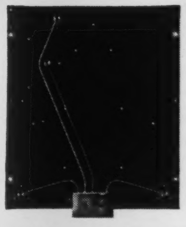
Easy to detach and interchange subassemblies

from backplate-manifold to vary desired control function; for cleaning or servicing.

Available Now for Prompt Delivery

4. RELAY PILOT with cleanable orifice and integral filters.

5. PEN MOVEMENT includes gearless index setting.



6. BACKPLATE-MANIFOLD supports subassemblies; conceals, supports, tubing; eliminates fittings. (Rear View)

MASON-NEILAN REGULATOR CO.
1210 ADAMS STREET, BOSTON 24, MASS., U. S. A.

Sales Offices or Distributors in the Following Cities:
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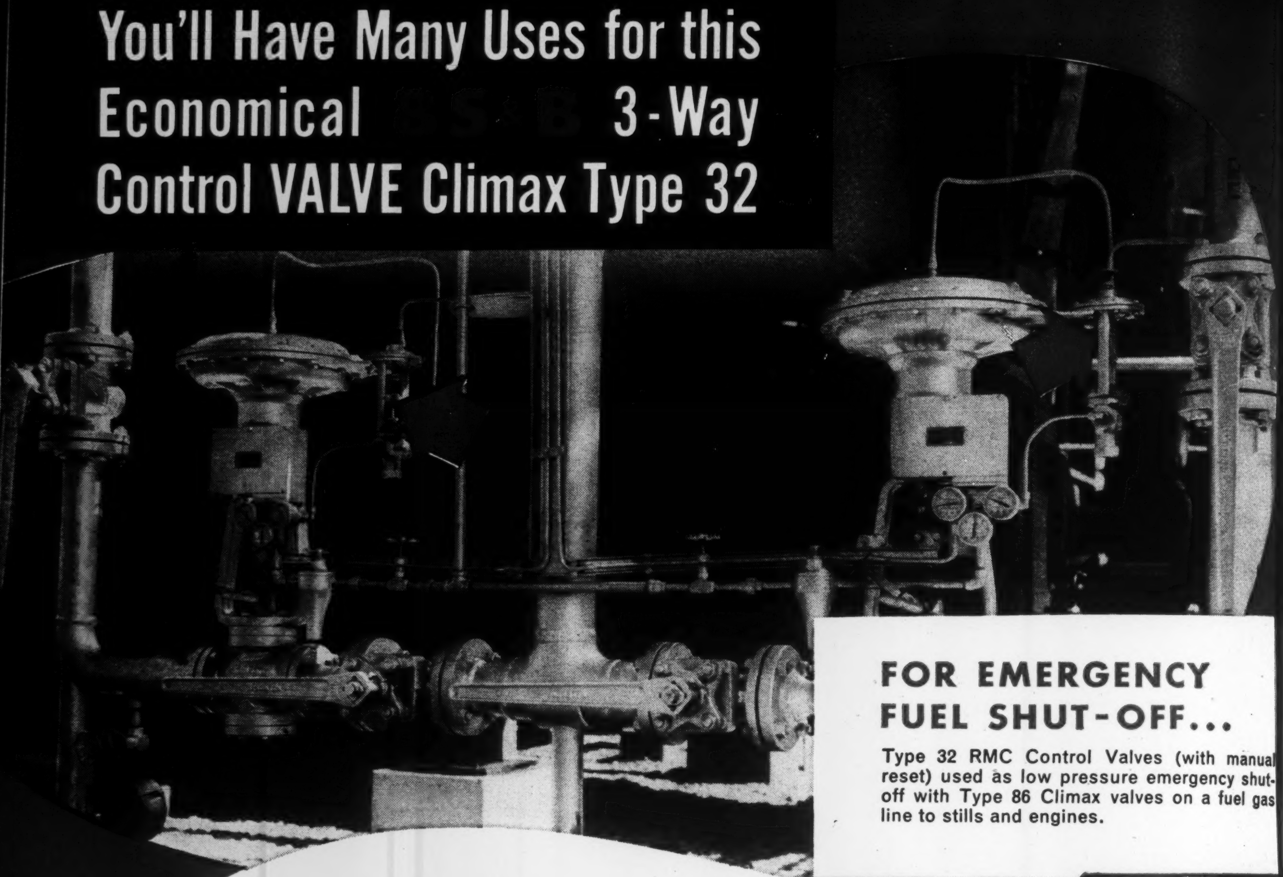
You'll Have Many Uses for this Economical BS&B 3-Way Control VALVE Climax Type 32



FOR EMERGENCY FUEL SHUT-OFF...

Type 32 RMC Control Valves (with manual reset) used as low pressure emergency shut-off with Type 86 Climax valves on a fuel gas line to stills and engines.

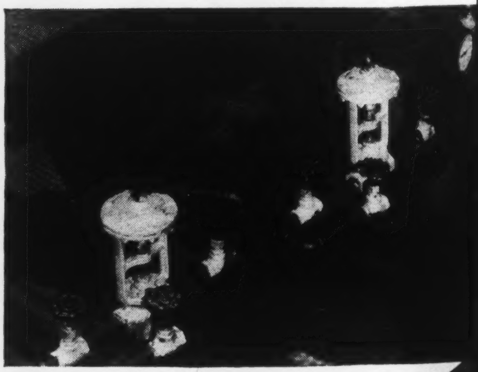
Designed for service with low differential pressure across the valve, having a small diaphragm area, Climax Type 32 Control Valve is both economical and versatile. As a three-way valve the spring holds the upper or horizontal ports closed when control medium is not applied to the diaphragm; as pressure is applied, the upper port opens for straight-through flow and the lower port closes.

To convert Type 32 to an inexpensive control or direct regulator it is only necessary to plug one of the valve outlets. Thus, with one horizontal outlet plugged (Type 32-D) with the bottom outlet plugged (Type 32-R). With these easy modifications you have, within their capacities, very efficient control valves, reducing regulators or back pressure valves. The Type 32 with hookup variations will serve many unique applications in safety shutdown systems or alarm signals.

The cast iron body, stainless steel inner valve and Neoprene diaphragm make Type 32 a rugged *and* versatile adjunct to your controls system.

FOR POWER CONTROL...

Climax Type 32-R valves used as automatic pressure controls to shut down pumps supplying low-pressure liquid-vapor separating vessel at over-pressure or pressure drop.



WRITE FOR Complete Literature on Type 32 and other Climax Diaphragm Control Valves. Ask for Catalog Section 105. Your nearest BS&B branch office has an expert on Climax Controls to assist you with your problems.

CLIMAX
BS&B
CONTROLS

BLACK, SIVALLS & BRYSON, INC.
Climax Controls Division, Dept. 4-V5
7500 E. 12th St. • Kansas City 3, Mo.

SCIENCE NEWS FOR YOUR HEAT-TREAT

For the first time, plant metallurgists can control carburizing by direct measurement of carbon in hot furnace gases.

Scientists have long known that the electrical resistance of a piece of steel will change whenever there's a change in the carbon content of the metal. This basic fact is now being put to work by many progressive metallurgists and heat-treaters. For L&N has applied the principle in a brand-new Primary Element called a Carbohm. In use, a Carbohm projects into the heat-treating furnace . . . looks rather like a thermocouple. Whenever the amount of active carbon in the furnace gas begins to increase or decrease, the Carbohm detects the change. An automatic controller connected to the Carbohm throttles the carbon supply up or down, to keep the furnace gas at desired strength. And a Micromax Recorder plots the result . . . as easy to read as a record of temperature.

The complete equipment—Carbohm, Controller and Recorder—is called Microcarb Control. Because the furnace and its temperature control must be designed to meet the needs of atmosphere regulation, Microcarb can be used only with the Series H Homocarb Furnace. It's our opinion—based on 35 years' experience in making fine heat-treating equipment—that any heat-treating department can do better work with Microcarb than by any other known means. And, because Microcarb adds another automatic control to the carburizing process, it should enable your plant to cut the costs of any carburized, mass-produced part or parts.

LEEDS & NORTHRUP CO.

Electrical Measuring Instruments **Automatic Controls**
Heat-Treating Furnaces

Jrl Ad TD4-623(5)

To top management, Microcarb means better competitive position for the individual company.

To production executives, Microcarb means closer following of production schedules, because carburizing speeds and results are definitely more predictable than ever before.

To personnel executives, Microcarb means cleaner, more attractive working conditions. And, if the heat-treat uses incentive pay, Microcarb helps heat-treaters increase their earnings, because it makes it easier for them to apply their skill and therefore increase their productivity.

To metallurgists, Microcarb means some or all of the above advantages, plus a tightening of technique such as every technician likes. "New" or hard-to-handle steels hold fewer puzzles. Standard steels emerge with closer specifications. The heat-treat takes another long step toward becoming a manufacturing laboratory.

Let us send you further facts about this new Microcarb Control. Just Check the coupon:

LEEDS & NORTHRUP CO.
4955 Stenton Ave., Phila. 44, Pa.

Please send Catalog T-623; Microcarb Control & Homocarb Furnaces

Please send Sec. 1 of Catalog T-623; Microcarb Control only

Name

Firm

Address

My title

MAGNETRON
PERMANENT MAGNETS
AND ASSEMBLIES

with
- ☆ **Die Cast Aluminum Jackets**
- ☆ **Sand Cast Aluminum Jackets**
- ☆ **Celastic Covers**

Complete assemblies with Permendur, steel or aluminum bases, inserts and keepers as specified. Magnetized and stabilized as required.

THE ARNOLD ENGINEERING COMPANY
SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION
General Office & Plant: Marengo, Illinois

Select FOR ACCURACY... AND YOU'LL ALWAYS BUY AMERICAN DIAL THERMOMETERS

Consistent accuracy — long-life service — have been associated with American Dial Thermometers for one hundred years! Every one is backed by the engineering skill and knowledge of materials, manufacturing and applications gained in more than a century of service to industry.

American Dial Thermometers are made in ranges from minus 60° to plus 1000°F. Selection is easy because we produce the greatest variety and offer the widest range of actuation in the dial thermometer business.

Mercury Actuation for rapid response, powerful action, extreme accuracy.

Vapor Pressure Actuation for accurate indication of temperatures at the most critical operating points.

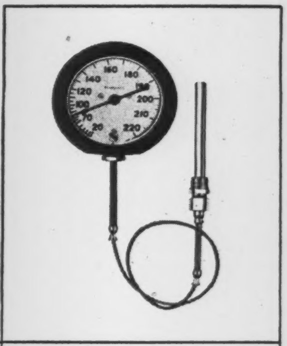
Gas Actuation for extremely high or extremely low temperature indications.

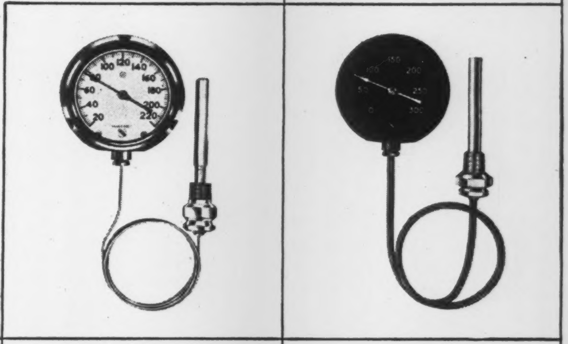
Bi-Metal Actuation for easy, fast, and economical installation.

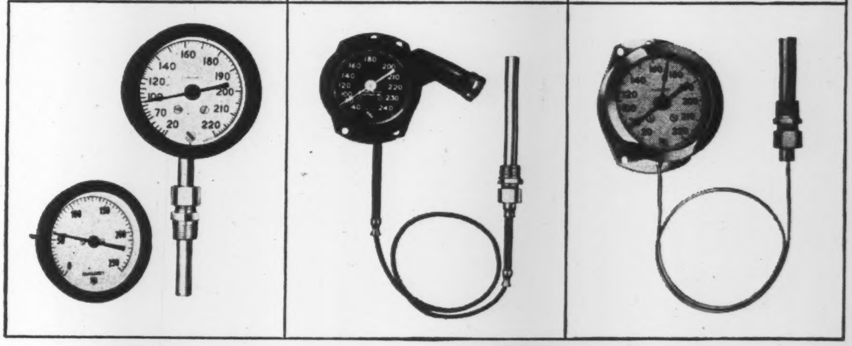
Easy Readability —provided with clear, bold numerals, accurately graduated dials, and pointer of contrasting color.

Rugged Construction — stainless steel movements, climate-resistant cases, heavy cover glass fronts, unique flush mounting flanges.

New Catalog contains full details about the complete American line, including industrial glass, dial and recording thermometers; electronic temperature indicators and recorders. Write for a copy.







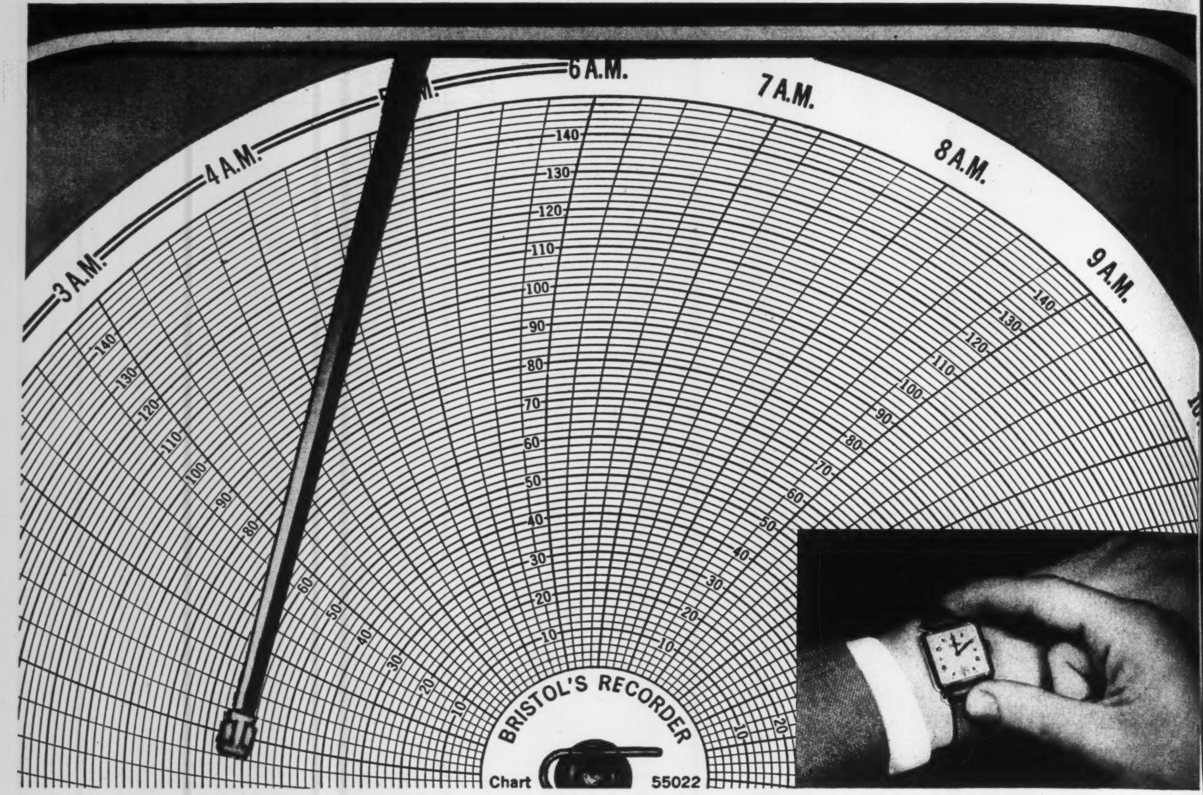
Pictured here are some of the many American Dial Thermometers stocked and sold by leading distributors.

1850
AMERICAN
U.S.A.

AMERICAN INDUSTRIAL INSTRUMENTS

MAXWELL
MANNING M&M & MOORE INC.
TRADE MARK

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONNECTICUT
MAKERS OF 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'HANCOCK' VALVES, 'ASHCROFT' GAUGES, 'CONSOLIDATED' SAFETY AND RELIEF VALVES. BUILDERS OF "SHAW-BOX" CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.


3 A.M.
4 A.M.
6 A.M.
7 A.M.
8 A.M.
9 A.M.
140
130
120
110
100
90
80
70
60
50
40
30
20
10
BRISTOL'S RECORDER
Chart 55022

No watch can be more accurate than its dial...

No recorder can be more accurate than its chart!

For accuracy's sake, insist on Bristol charts for your Bristol recorders.

The chart is the scale that marks the recorder's measurements. Since only Bristol knows what those measurements are, only Bristol can make charts to record them accurately.

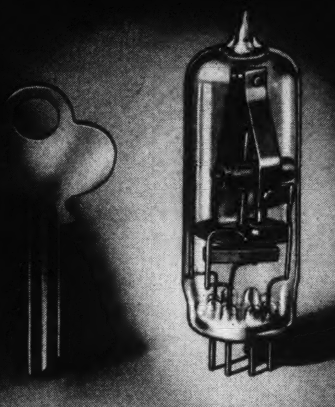
Bristol charts *do not* contain fillers, which cause poor inking, pen failure.

If you use a sizable quantity of Bristol charts a year, ask about our Chart Purchase Plan for savings up to 50%. Address The Bristol Company, Chart Division, 113 Bristol Road, Waterbury 20, Conn.

Only BRISTOL
made-to-measure
for BRISTOL recorders!

BRISTOL *The dependable Guidepost of Industry*

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS



SCARCELY LARGER THAN YOUR DOOR KEY

FOR . . .
Cathode Protection
Gyro Erection
Motor Starting
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Emergency Circuit Switchovers

Announcing
. . . a NEW Miniature by EDISON

EDISON announces its new Model 207 Miniature Thermal Relay – designed to meet the need for a space-saving time-delay relay.

Into the design and development of this sealed-in-glass miniature, EDISON has applied the experience of over 20 years in the thermal engineering field and has built into it many of the quality features of the widely-used EDISON Model 501 Thermal Relay. In numerous applications the two relays have similar operating characteristics.

Pilot production started in December 1951. For free bulletin, just clip coupon and mail.

Thomas A. Edison
INCORPORATED
Instrument Division • West Orange, N. J.

To: Instrument Division, THOMAS A. EDISON, INC.
63 Lakeside Avenue, West Orange, New Jersey

We may have an application for your Miniature Thermal Relay to____________________
____

Please send bulletin I-6 to:____________
Name and title____________________
Company_______________________
Address________________________
____

SPECIFICATIONS • MODEL 207

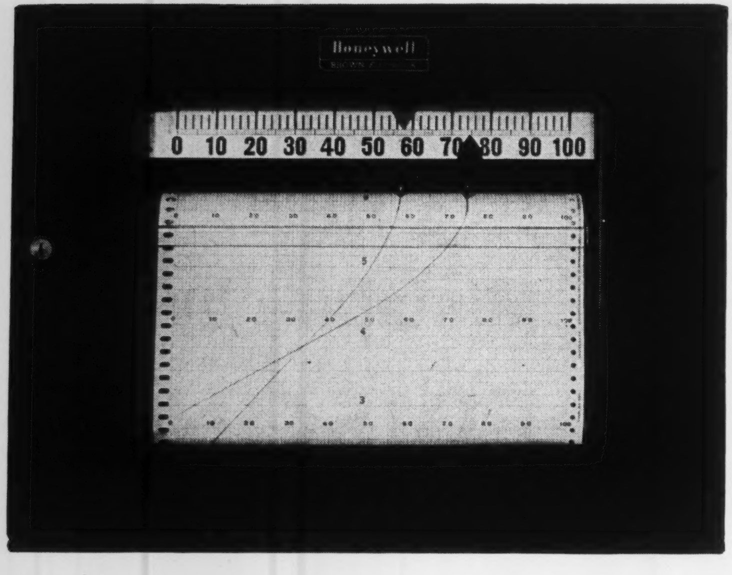
Sealed-in-glass
Arc quenching atmosphere
Precision timing — Final adjustment made *after* sealing by patented feature
Weight: ½ oz. (approx.)
Diameter: ¾" (approx.)
Height: 2¼" maximum (seated)
Standard Heater Voltages: 115v, 27.5v, 6.3v
Contact Ratings: 2.5 amps @ 125v ac., 1.0 amp @ 125v dc.
Ambient Compensation: −60 to +85°C
Nominal Heater Input: 2 watts
Mounting: Miniature Button 7-pin
Range of Delay Periods: 5 secs. to 120 secs.

●

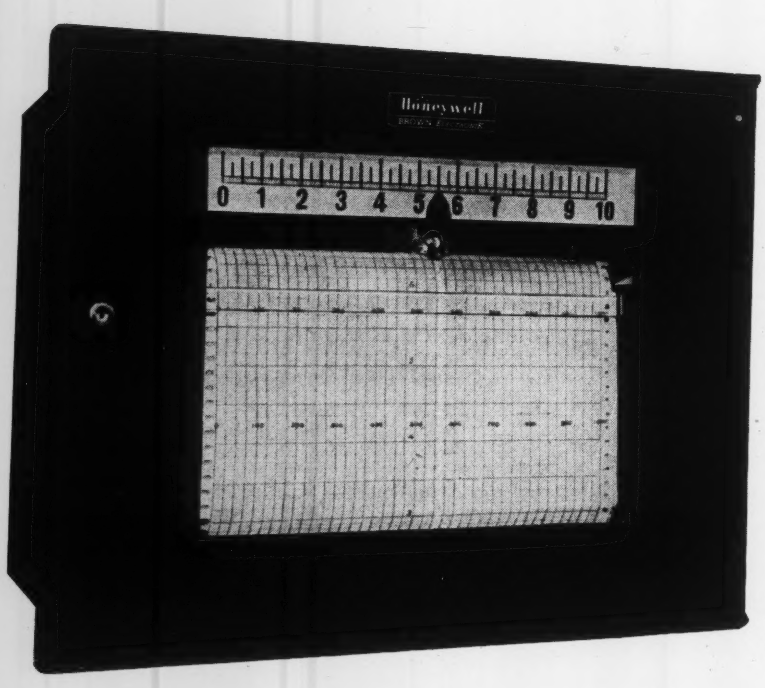
OTHER INSTRUMENT DIVISION PRODUCTS

Sealed Thermostats
Sensitive Relays
Temperature Monitors
Electrical Resistance Bulbs

YOU CAN ALWAYS RELY ON EDISON


Honeywell
BROWN ELECTRONIK
0 10 20 30 40 50 60 70 80 90 100

Two versatile instrument fo


Honeywell
BROWN ELECTRONIK
0 1 2 3 4 5 6 7 8 9 10

● ***Important Reference Data***

Write for Data Sheet No. 10.0-7 on the *ElectroniK* High Speed Recorder . . . Data Sheet No. 10.0-6 on the

THE *ElectroniK* DUPLEX RECORDER

simultaneously records two variables on one chart

No more need for tedious, time-consuming cross comparison of related measurements! Now, on a single chart, the *ElectroniK* Duplex Recorder records any two variables at the same time. This instrument has two independent continuous-balance measuring systems, each driving its own recording pen. Each pen traverses the full eleven inches of chart width without interference.

Standard chart drive mechanism permits both variables to be recorded as a function of time . . . or with a Selsyn motor drive, chart motion can be readily related to a third variable, such as motion or displacement. Both measuring circuits are standardized simultaneously at the operation of a single push-button. Auxiliary switches can be supplied to operate signals or controls from one of the pens. A solenoid-actuated third pen can be provided to register in time conformance with one of the standard pens.

Saves valuable panel space, too; *one* instrument does the work of *two*!

for laboratory or plant . . .

THE HIGH-SPEED *ElectroniK* RECORDER

accurately records fast-changing variables

Now—with this new instrument—you can accurately record signals of full-scale amplitude which vary as rapidly as 20 cycles per minute. Signals with peak to peak amplitude of 10% of scale can be reproduced at variations up to 3 cycles *per second*. Particularly useful in test or production measurements of quickly-changing temperatures, pressures, or other variables, this *ElectroniK* model can be employed in conjunction with thermocouples, *Radiamatic* pyrometers or any other sensing elements which produce a d-c signal.

The recording pen can traverse the *eleven-inch* wide graduated chart in only *one second*. A motor-driven reroll mechanism maintains uniform tension on the chart, for maximum accuracy of records. Chart speeds up to 4″ per second are available. Push-button standardization; adjustable damping circuit.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4482 Wayne Ave., Philadelphia 44, Pa.

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

the *ElectroniK* Duplex Recorder.

ALUMINUM MONEL* BRASS STEEL INCONEL* STAINLESS STEEL NICKEL* COPPER

NEED METALS?

Sheet, Plate, Tube, Pipe, Wire, Rod and Bar, Extrusions, Structural Shapes . and the following INDUSTRIAL PRODUCTS: Fasteners, Tube Fittings, Pipe Fittings, Valves, Silver Brazing Alloy, Welding Material, Solder, Castings, Tube Expander Equipment, Liquid Plastic Protective Coating, Metallic Caulking Compound, Aluminum Metal Trim, Waterproof Barriers, Nails, Handrail Fittings, Low Melting Alloys, Aluminum Jacketing, Wire Cloth and Rope, and "O" Rings.

Precision Equipment for Shearing and Slitting.

*Not stocked in Kansas City or St. Louis territories.

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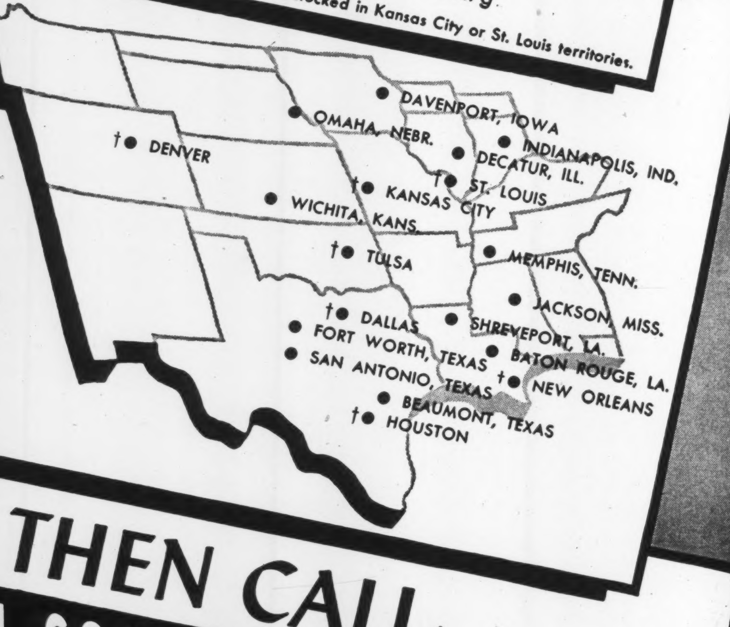
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INSTRUMENTS FOR LABORATORIES

Laboratory Finds Portable Double Bridge Ideal for Transformer Heat-run Tests

0.00004-ohm resistance changes measured with G-E double bridge

The General Electric portable double bridge provides a simple method of measuring the precise resistance values of a transformer's windings during heat-run tests, a large industrial laboratory reported recently.

HIGH ACCURACY

Because of its high accuracy, the bridge has been found ideal for measuring resistance changes in the order of 0.00004 ohms encountered during transformer temperature-run tests. This degree of accuracy is important when making these measurements because the readings are multiplied many times in computing the temperature. Thus, even a minute error greatly affects the calculation.

EASY OPERATION

Designed for easy operation, the G-E portable double bridge has only one dial to adjust while making the measurement. For maximum utility, it has eight ranges that permit measurements extending from 0.0001 to 22 ohms. It is accurate to 0.1 per cent of full-scale value, e.g., 0.000001 ohms at the lowest range.

OWN POWER SOURCE

The bridge saves time in measuring resistance because it contains its own power source and needs only one operator. Its price: only $304.20*. For more information, check coupon for Bulletin GEC-251.

Oscillograph Simplifies Wave Analysis

ON-THE-SPOT TESTS of plant generators are made easily with the G-E Type PM-10 Oscillograph. This multi-element oscillograph quickly determines wave shape; from that, form factor may be calculated and complete wave-analysis charts prepared.

The advantage of the PM-10 in this application is its high-speed. This makes it possible to "draw out" wave shapes so that the ordinates for wave analysis can be more accurately and easily measured.

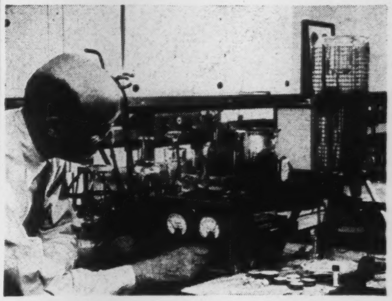
The PM-10 will operate at film speeds up to 1200 feet-per-minute, and it can be equipped with any number of galvanometers up to 12. Additional features include timing lines and simultaneous viewing with recording.

Prices for the PM-10 start at $4000*. For more information check the coupon for Bulletin GEC-449.

1952 CATALOG

G-E Measuring Equipment

80 pages describing all of General Electric's testing and measuring devices. For free copy check GEC-1016 in coupon at right.



G-E Thermocouple Vacuum Gage Aids Metal Evaporation Process

The General Electric Research Laboratory is currently using approximately 200 G-E thermocouple vacuum gages in its research sections. Typical of many of the applications to which these gages have been applied is the one shown above. Dr. L. R. Koller, scientist at the laboratory, is pictured working on a process which evaporates metal coatings onto insulating surfaces.

IMMEDIATE READINGS

Dr. Koller said, "I find this G-E gage entirely satisfactory for this operation. It can be installed in the vacuum system easily and it gives continuous vacuum readings".

LOW COST

The G-E gage provides a convenient means of measuring pressures from 1 to 500 microns. It can be supplied for either glass or metal vacuum systems and is available in either a-c or battery-operated types. Price is $117.58*. Check GEC-385 in coupon below for more information.

*Manufacturers suggested price

SECTION B605-15, GENERAL ELECTRIC
SCHENECTADY 5, N. Y.

Please send me the following bulletins: Indicate:
√ for reference only
X for planning an immediate project

☐ Thermocouple Vacuum Gage GEC-385
☐ Portable Double Bridge GEC-251
☐ Type PM-10 Oscillograph GEC-449
☐ 1952 Catalog GEC-1016

NAME..

COMPANY..

STREET..

CITY.................... ZONE.......... STATE..........

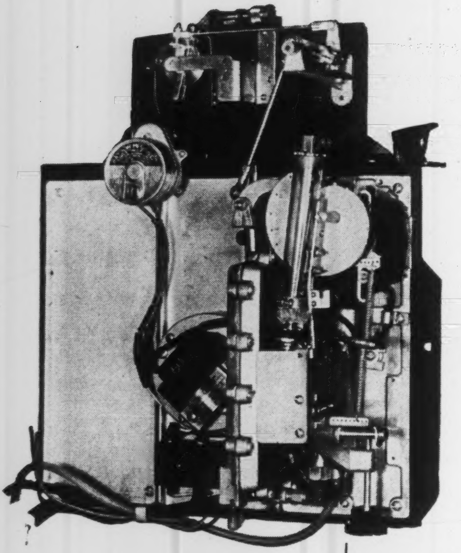
GENERAL ELECTRIC

a new low differential flow meter to measure . . .

air flow

gas flow

or air flow-gas flow ratio



hays *Diaflow* meter

The Hays Diaflow Meter is a *new* low differential flow meter for measuring air flow, gas flow or recording the ratio of air flow to gas flow. Especially adaptable for industrial furnaces and sewage disposal plants, the Diaflow meter is used as a guide in achieving product, process and cost control.

Employing the pilot method of operation the diaphragm measuring element will accommodate static pressures up to 10 lbs. and differential pressures up to 20″ water. Write today for Bulletin 52-1017-37 containing complete information on the new Diaflow meter.

features

PILOT METHOD
provides higher sensitivity and greater accuracy . . . no load placed on measuring element.

DRY, DIAPHRAGM MEASURING
—no messy fluids . . . no leveling required.

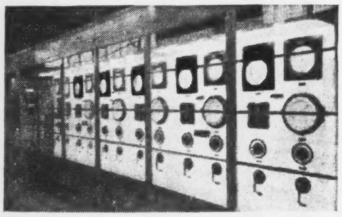
UNIT CONSTRUCTION
—easy parts removal without affecting calibration.

PIVOTED CONSTRUCTION
—internal parts accessible from front of case . . . no special tools required.

HIGHLY ADAPTABLE
—wide variety of models fit most measuring requirements.

DUAL FLOW
—gas and air flow records can be coordinated for efficient combustion.

applications



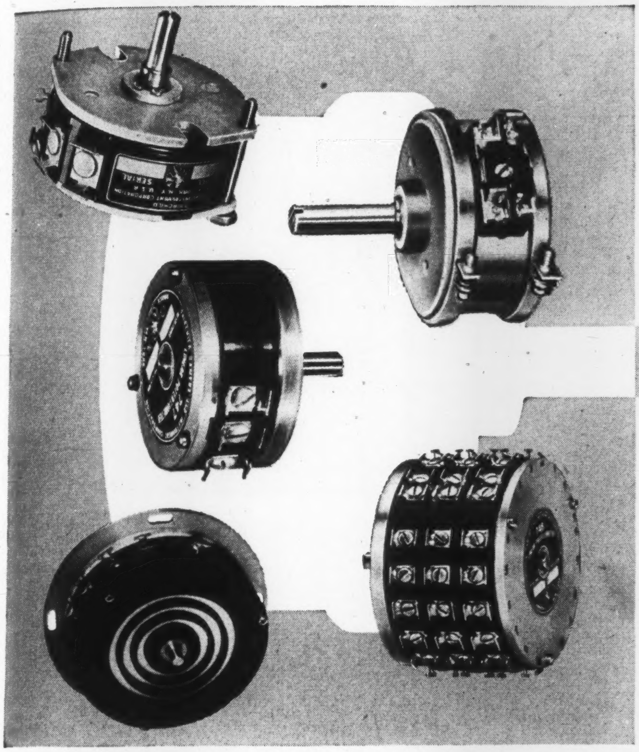
Industrial Furnaces—Diaflow measurement in open hearth, soaking pit, billet, slab heating and annealing furnace indicates excessive amounts of air and/or gas . . . helps to prevent fuel and gas waste . . . serves as a guide in maintaining product quality.

Sewage Disposal Plants—A guide to proper control of sewage treatment processes. Diaflow metering indicates: load on plant, variations in functions, relative rate of fluid flow and a continuing check on costs.

Automatic Combustion Control
Boiler Panels • Hays-Penn Flowmeters
Veriflow Meters and Veritrol
Gas Analyzers • Draft Gages
Combustion Test Sets • CO_2 Recorders
Electronic Oxygen Recorders

THE hays CORPORATION
MICHIGAN CITY 8, INDIANA

Where control accuracy is important... use Fairchild Precision Potentiometers



In many control systems, accuracy is the all-important factor. But the accuracy of an entire system depends on the proper functioning of each component.

Fairchild precision potentiometers are designed and built to meet extreme accuracy requirements. That's why they are being selected more and more for control systems where accuracy, limited weight and space, and simplicity are paramount.

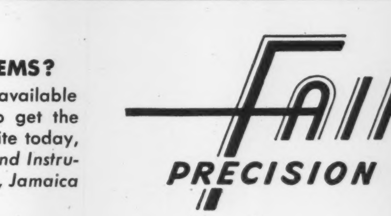
These potentiometers perform mathematical computations in electrical computing systems for machine-tool controls, aircraft instruments, aerial-camera controls, radar, guided missiles, gunsights, and analog computers of all types. They are available in non-linear and linear types and in ganged combinations of either or both, with windings to meet your requirements. If you have computer or control problems, ask for our recommendations about using Fairchild Precision Potentiometers to solve them.

HOW PRECISION IS DESIGNED AND BUILT INTO FAIRCHILD POTENTIOMETERS

1. Shaft is centerless-ground from stainless steel to a tolerance of +0.0000, −0.0002 in. which, together with precision-bored bearings, results in radial shaft play of less than 0.0009 in.

2. Mounting plate has all critical surfaces accurately machined at one setting to insure shaft-to-mounting squareness of 0.001 in./in. and concentricity of shaft to pilot bushing within 0.001 in. FIR.

3. Housing is precision-machined from aluminum bar stock. Close tolerance of this construction permits ganging up to 20 units on a single shaft with no eccentricity of the center cups, even though only two bearings are used for the entire gang.



4. Windings are custom-made by an exclusive technique. Guaranteed accuracy of windings in standard types is: linear, 0.5%; non-linear, 1.0%. Higher accuracies (to 0.05%) are available in other types. Guaranteed service life is 1,000,000 cycles.

DO YOU HAVE CONTROL PROBLEMS?

Fairchild Sample Laboratory engineers are available to help you with potentiometer problems. To get the benefit of their knowledge and experience write today, giving complete details, to *Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, New York, Department 120-26B.*

FAIRCHILD

PRECISION POTENTIOMETERS

a new low diff

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VOLTS
D.C.
WESTON
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MICROAMPERES
WESTON
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40
50

Among the things you take for granted...

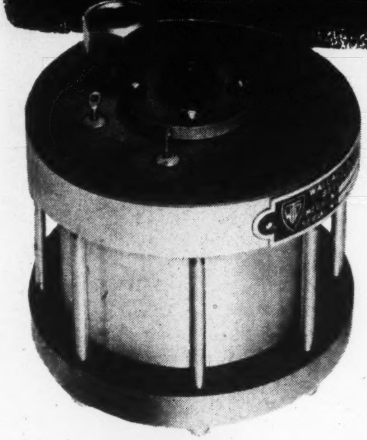
The strong conviction instrument users hold for *measurements by* WESTON has its foundation in their own instrument experience . . . years during which WESTON instruments have given unfailing service . . . proved beyond doubt their unequalled precision, stamina and dependability. It is evident in the widespread preference shown for WESTON instruments for panel and built-in needs . . . where *so much* depends on the movement of a pointer. Regardless of the service . . . or the type, range or sensitivity of the instrument . . . truthful measurements and long, carefree service are *taken for granted*. Copy of panel instrument bulletin A7C gladly sent on request. WESTON Electrical Instrument Corporation, 617 Frelinghuysen Avenue, Newark 5, New Jersey . . . manufacturers of Weston and TAGliabue instruments.

WESTON *Instruments*

9360

FOR DEEP VACUUM OPERATIONS

W&T PRECISION INSTRUMENTS



FA-193

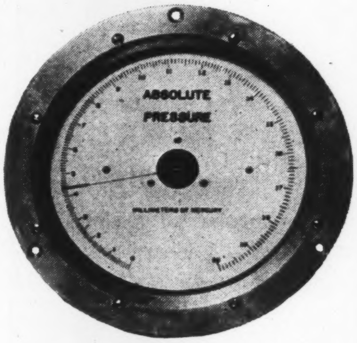
THE W&T ABSOLUTE PRESSURE CONTACTOR

This sensitive, yet durable aneroid device is used for actuating an electric circuit at a preset value of absolute pressure.

Outstanding features of the Contactor, type FA-193, include:

Range of adjustment	0-2 mm Hg. and other ranges made to customer's specifications up to 800 mm Hg. absolute pressure.
Sensitivity	will make or break within 0.10 mm Hg.
Contact capacity	5 ma at 115 volts A.C.
Repeatability	0.10 mm Hg.

Vacuum-tight construction
Over pressure protection



FA-160 0-20 Scale

THE W&T ABSOLUTE PRESSURE INDICATOR

This precision instrument is used for quick, dependable indications of absolute pressures in the vacuum range. Pressure readings are independent of the nature of the gas. It is available in two dial sizes — 2¾″ and 6″.

Other features of the Indicator, type FA-160, include:

Range	0-20, 0-50, 0-100, 0-200, 0-410 and 390-800 mm Hg. absolute pressure.
Sensitivity	One part in 500
Accuracy	One part in 300

Over pressure protection
Direct readings
Rugged vacuum-tight construction

0-100 Scale

THE W&T ABSOLUTE PRESSURE CONTROLLER

The Controller with its associated Electronic Relay furnishes precision control of absolute pressure and provides a continuous indication of absolute pressure. Independent adjustment of the "high" and "low" contacts is made through a magnetic clutch thus eliminating stuffing boxes and seals and ensuring leak-tight operations.

Outstanding features of the Controller include:

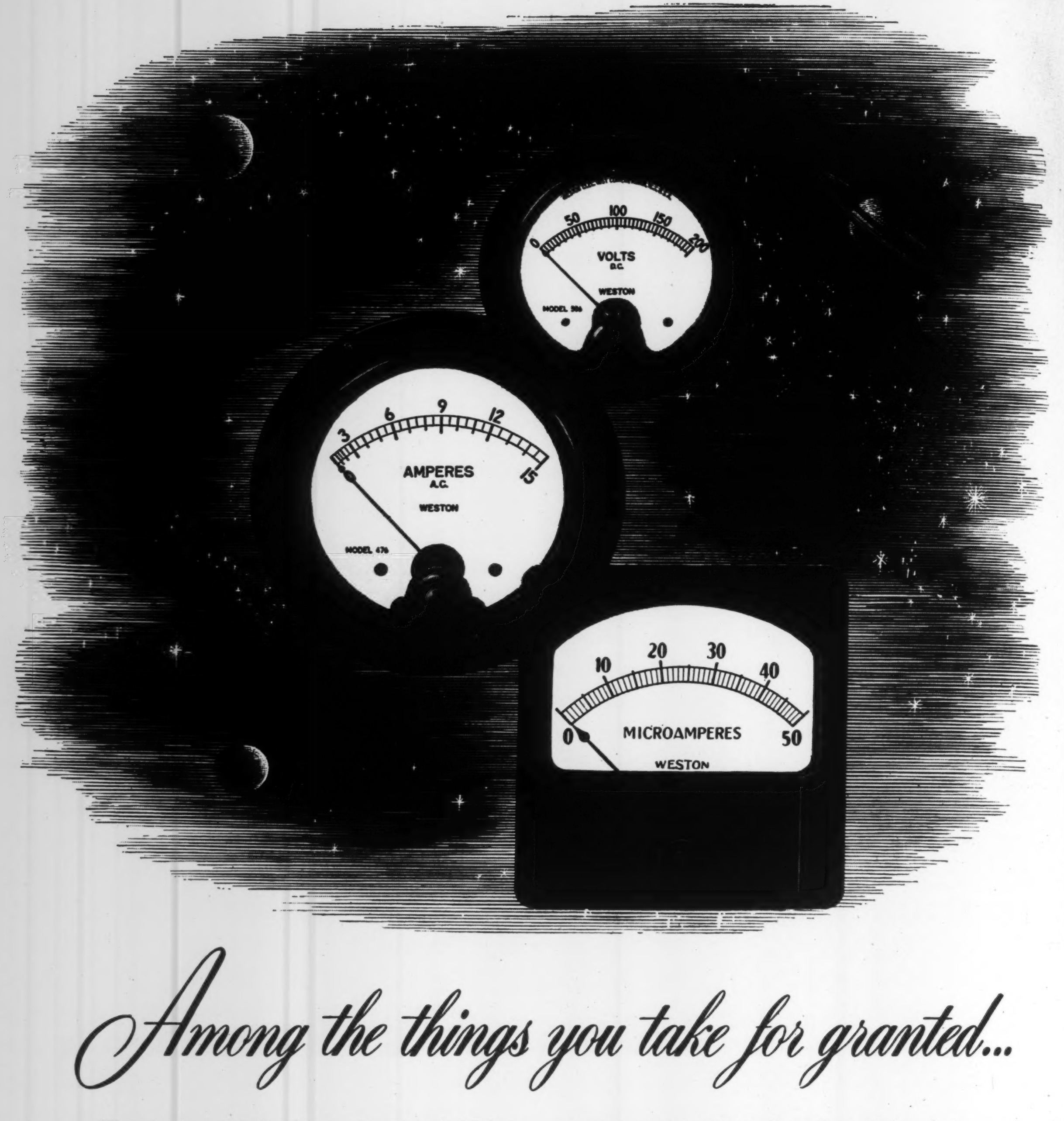
Range	0-20, 0-50, 0-100, 0-200, 0-410 and 390-800 mm Hg. absolute pressure.
Sensitivity	One part in 500
Accuracy	One part in 300
Relay contact capacity	5 amps, 110 Volts, 60 cycles non inductive load.

Fast accurate response
Over pressure protection
Vacuum-tight construction

Additional Information Will Be Supplied On Request

WALLACE & TIERNAN
PRODUCTS, INC.
ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
Belleville 9, New Jersey • Represented in Principal Cities

A-85



Among the things you take for granted...

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9360

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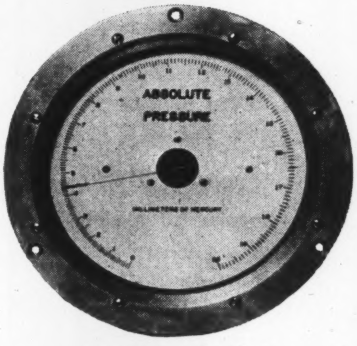
W&T PRECISION INSTRUMENTS

FA-193



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A-85

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Vacuum-tight construction	
Over pressure protection	

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Fast accurate response	
Over pressure protection	
Vacuum-tight construction	

Additional Information Will Be Supplied On Request

WALLACE & TIERNAN
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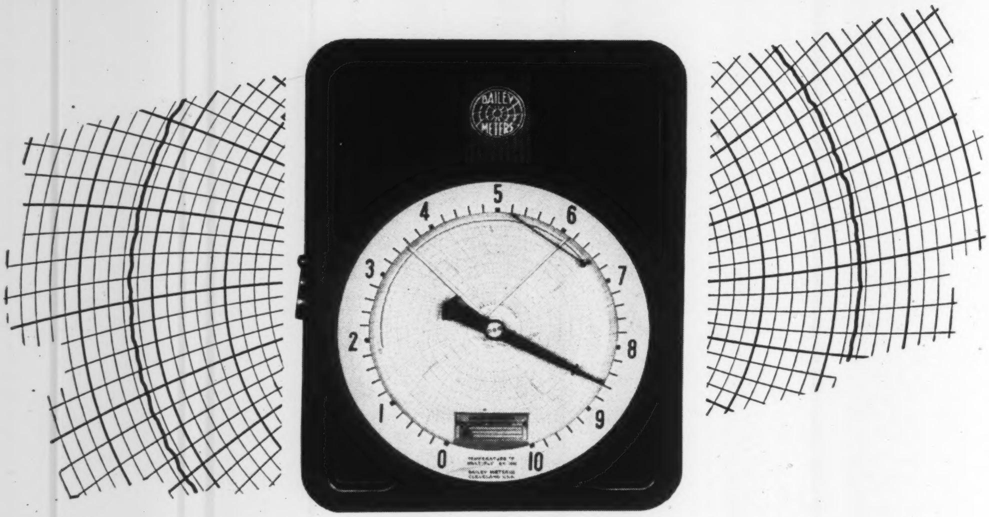


Looking for Better Temperature Instruments?

...Then check these features of Pyrotron Electronic Resistance Thermometers...

FUNDAMENTAL ACCURACY

Bailey Pyrotron Resistance Elements are made of highest purity platinum—the material used by the National Bureau of Standards in establishing basic standards for temperatures from −190°C to +660°C.

THREE TYPES OF CONTROL

Pyrotron Controllers may operate: on-off electrical systems by either electronic relays or electric contacts, modulated electronic systems, or air-operated systems. Two temperatures may be recorded on the same chart and controlled by a single instrument.

FACTS PUT INTO USABLE FORM

Bailey Pyrotrons may be arranged to put temperature facts into convenient usable forms. If two or more temperatures are related, they may be recorded as continuous records on the same chart for easy comparison. The average of several temperatures or the difference between two temperatures may be recorded as a single continuous record which may be retransmitted to a distant point or used to actuate a control system.

EASY INSTALLATION

Bailey Pyrotrons do not require careful leveling or protection against vibration. Three ordinary copper wires are all that is needed to connect each temperature sensitive element with the recorder. Power may be taken from any 115 volt 60 cycle circuit.

MINIMUM MAINTENANCE

The absence of galvanometers, batteries and standardizing equipment, together with the use of interchangeable unit assemblies, reduces Pyrotron maintenance to the vanishing point.

ABUNDANT POWER

A separate motor drive for each temperature furnishes abundant power to operate a recording pen, a controller and an alarm switch.

For the full story on this unusual electronic resistance thermometer which is suitable for ranges between —300°F and 1200°F, ask for Bulletin No. 230-C.

P-21

BAILEY METER COMPANY

1041 IVANHOE ROAD • • • CLEVELAND 10, OHIO

Controls for Processing

TEMPERATURE
PRESSURE
% OXYGEN
% COMBUSTION

FLOW
LEVEL
DENSITY
RATIO

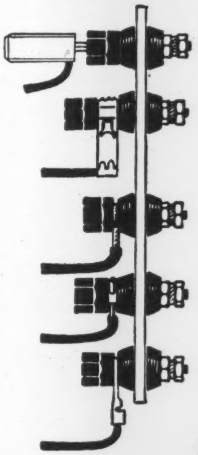
FIRST CHOICE on EQUIPMENT of FINE QUALITY

AVAILABLE IN
BLACK and RED
ACTUAL
SIZE

More and more leading manufacturers are using 5-WAY Binding Posts to provide increased flexibility and improved performance of their electrical and electronic equipment.

SUPERIOR 5-WAY BINDING POSTS

1. **Plug-in for standard 3/4" banana plug**
2. **Clip-lead to shaft**
3. **Wire looped around shaft and clamped**
4. **Wire (up to #12) permanently clamped through center hole**
5. **Clamped spade lug connection**



Better electrically *and* mechanically, the rugged SUPERIOR 5-WAY Binding Post affords quick, safe and positive connections for practically every application. Mounting in any panel from 1/16" to 1/4" is easily accomplished by means of a single keyed or unkeyed hole. It provides complete insulation from the panel. Construction is extra strong. Only the most durable of phenolic plastics is used. The hexagonal shaped head can be tightened with a 1/2" socket wrench without damage. Current capacity is 30 amperes; working voltage is 1000 volts. The color choice of RED or BLACK permits ready circuit or polarity identification.

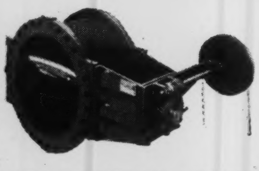
A FREE SAMPLE IS AVAILABLE IF REQUESTED ON YOUR LETTERHEAD.
705 THURE AVENUE, BRISTOL, CONNECTICUT

THE SUPERIOR ELECTRIC CO.
BRISTOL, CONNECTICUT

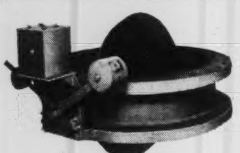
POWERSTAT Variable Transformers • STABILINE Automatic Voltage Transformers • VOLTBOX A-C Power Supplies
VARICELL D-C Power Supplies • POWERSTAT Light Dimming Equipment

R-S valvEvents

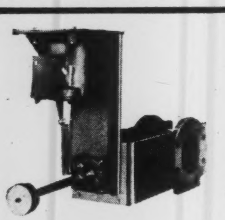
• EXCERPTS FROM THE R-S BOOK OF EXPERIENCE •



WATER SERVICE—No. 825—36-inch 125-pound cast iron valve equipped with 18—8 shafts, bronze bushings and rubber seat for 85-pound drip tight shut-off.

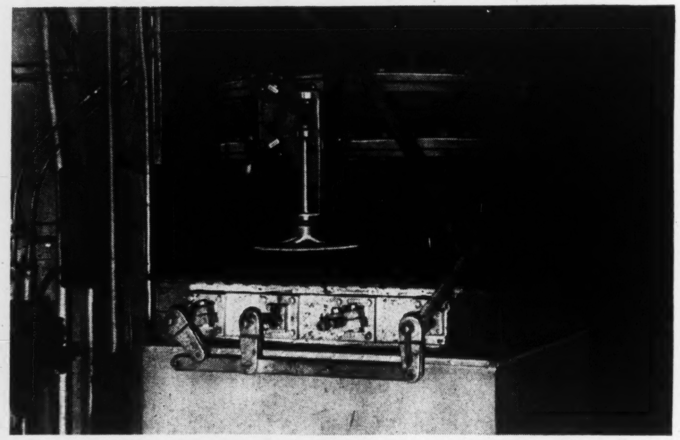


EMERGENCY OIL SERVICE—No. 628—solenoid trip valve. Should the solenoid function, the latch is tripped which causes the counterweight to open or close the valve by gravity. Available in any metal or alloy and in various sizes for emergency shut-off or vent for air, gas, steam, oil, and water.

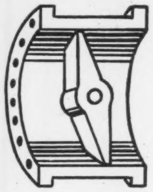


700° F. EXHAUST GAS SERVICE—No. 826—6-inch 125-pound R-S "H" metal valve used on small turbine generator. Equipped with 18—8 shafts, hastelloy bushings, finned lubricated stuffing box and solenoid trip mechanism.

STEAM SERVICE—No. 677—1500-pound welding end steel valve for superheated steam—A. S. M. E. Standards.



SEMI-SOLID SERVICE including abrasive and corrosive materials.



R-S VALVES

Control and Shut Off

Practically Any Material

The beveled vane seats firmly at a 12½° angle and is closed from a fully open position through 77½° of arc by either manual or automatic operation. A metal-to-metal seat gives satisfactory commercial shut-off. When required, Monel or stainless steel can be welded to the vane periphery and a babbitted seat used in the valve body. Drip tight or bubble tight closure can be obtained with a rubber seat.

Power controlled prime movers delivering the necessary foot pounds of torque open or close these self-cleaning valves at any desired speed from one second to eight minutes according to requirements. Pressures range from 2 to 2500 psig and temperatures from minus 300° F. to plus 2000° F.

Such simplicity of design, adaptability and operating ease are the reasons why R-S Valves can be installed to control and shut off the volume and pressure of any material that flows or is forced through a pipe.

Obtain full details from your R-S representative.

R-S PRODUCTS CORPORATION
4600 Germantown Avenue, Philadelphia 44, Pa.
An S. Morgan Smith Company Subsidiary

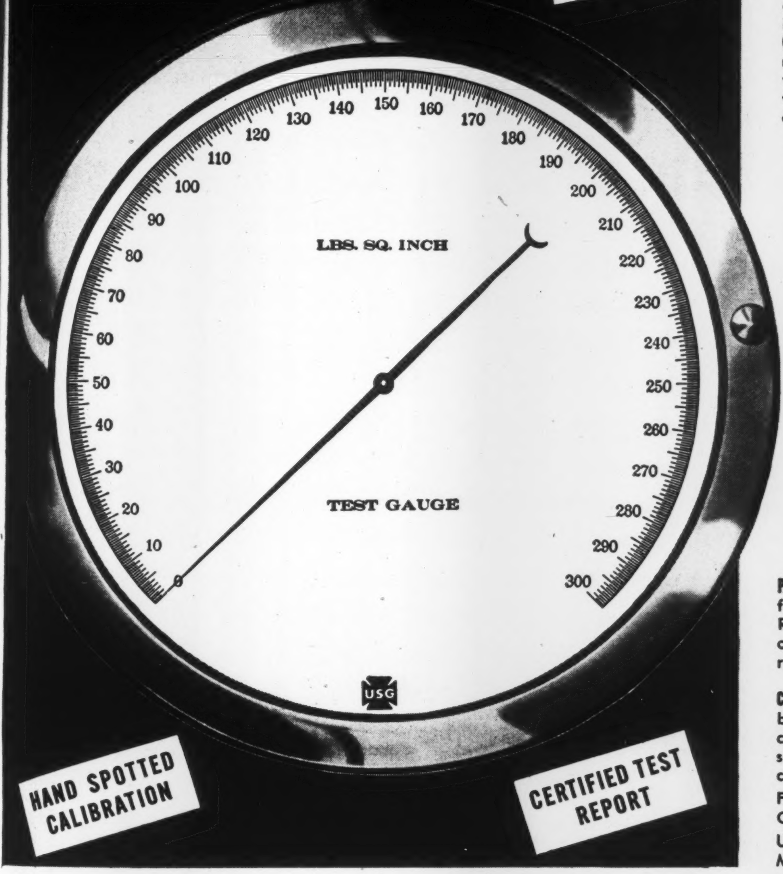
DISTRICT OFFICES IN PRINCIPAL CITIES

For Peak Precision

"300,000 LB. CAPACITY RIEHLE COMPRESSION TESTING MACHINE, MADE BY RIEHLE TESTING MACHINE DIVISION OF AMERICAN MACHINE AND METALS, INC."

USG LABORATORY TEST GAUGES

Wherever you require *peak precision* from a gauge—for compression or tensile strength testing machines, or for replacing or supplementing dead weight testers or manometers—you can use the accuracy of USG Laboratory Test gauges to advantage.



PEAK PRECISION—½ of 1% of the indicated reading above 20% of the maximum dial range and one part in 500 (0.2%) below 20% of the maximum dial range. A Certified Test Report is furnished without charge for applying corrections when instrument is used at accuracies higher than ½ of 1% of indicated reading.

PRECISION DRAWN TUBE—Drawn from phosphor bronze, beryllium copper, or 403 stainless steel—depending on pressure range. All tubes are specially treated to produce minimum hysteresis and drift.

PRECISION MOVEMENT—Aircraft quality for highest sensitivity. Nickel-dipped bronze with extra long bearings and heavy bronze bushing fitted with nickel silver pinions and arbors.

PRECISION CALIBRATION—Graduations are individually hand-spotted and engraved on a white background. Dial may be rotated 10° for zero adjustment to compensate for preloading.

DIAL SIZES—12" and 16".

PRESSURE RANGES—All pressure ranges from 30" Vacuum and 15 to 20,000 p.s.i. Ranges over 30,000 p.s.i. on special order. Suppressed scales available on request.

CASE AND RING—Cast aluminum case, black finish. Cast brass ring with polished chromium finish. Flush panel mounting or surface mounting with back or lower connection.

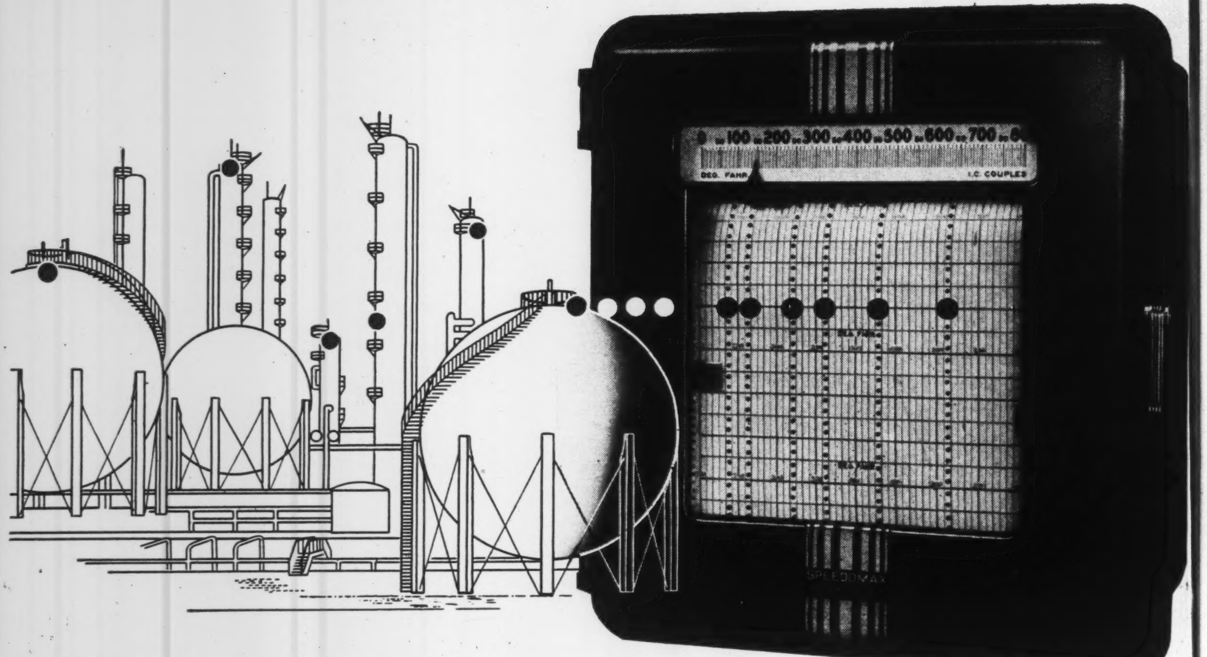
For additional information, write for USG Catalog 64.

United States Gauge, Division of American Machine and Metals, Inc., Sellersville, Pa.

Quality Gauges Engineered for Enduring Accuracy UNITED STATES GAUGE

PRODUCTS OF UNITED STATES GAUGE . . . Absolute Pressure Gauges • Aircraft Instruments • Air Volume Controls • Altitude Gauges • Boiler Gauges Chemical Gauges • Mercury, Gas, and Vapor Dial Thermometers • Glass Tube and Industrial Thermometers • Flow Meters • Inspectors' Test Gauges Precision Laboratory Test Gauges • Marine, Ship and Air-Brake Gauges • Voltmeters • Ammeters • Welding Gauges.

OTHER DIVISIONS OF AMERICAN MACHINE AND METALS, INC. AT SELLERSVILLE, PA.: GOTHAM INSTRUMENTS, AND AUTOBAR SYSTEMS.



A new temperature Fact every 2 sec!

Today, when many refinery operations may need temperature facts within seconds instead of minutes, the Speedomax story is worth knowing:

For a Speedomax Multiple-point instrument's record-printing "wheel" darts from temperature to temperature in just 2 seconds per point! Thus, if there are, say, 15 fairly important temperatures on a single refinery unit, each one can actually come up and be recorded as often as twice per minute, automatically and continuously.

Two extra checks for vital temps

But suppose a few points require even closer watching, or more frequent recording? Speedomax handles them, too, in either of two ways:

First, they can be recorded more frequently than the other points, in such a sequence as 1, 2, 1, 3, 1, 4, etc.

Second, the vital points can be recorded in greater detail than the other points. This is done by giving the instrument an additional range which is used only with the pre-selected points. This range puts far fewer degrees-per-inch across the instrument's scale; it thus "spreads" the reading for detail.

Ability to measure temperature from any source and across either wide ranges or the new narrow ranges is another L&N specialty. Selection among thermocouples, Thermohms and Rayotubes will determine the correct sensing element. Selection among various recorder components will put the information on paper in the desired form.

160 temps on one instrument

For these and many more features . . . for instance, 160-point models . . . credit Speedomax's refined, stable, dependable construction, both electrical and mechanical. Too, Speedomax is not affected by vibration; never needs levelling up; can measure many quantities besides temperature.

Any L&N office, including 4955 Stenton Ave., Phila. 44, Pa., will send the Speedomax story on request.

LEEDS NORTHRUP

Jrl. Ad. ND46-700(2)

EDITORIALS

An Inquiry and A Reply

EVERY month, *Instruments* receives many inquiries requesting information on instrumentation problems. Mr. Eugene Finch, of the Chemical Engineering Department of North Carolina State College, requests constructive suggestions for a new course in Process Measurement and Control. The reply to his inquiry might help others with the same problem.

Dear Mr. Aronson: We have just instituted a course in Process Measurement and Control in the Department of Chemical Engineering and I am looking for a suitable text and constructive suggestions. I should appreciate any suggestions you may have regarding text books for the course.

EUGENE B. FINCH

Dear Mr. Finch: As I am now teaching the graduate course in Process Instrumentation at the University of Pittsburgh (Chem. Engineering Dep't), I will tell you of my experience.

I am using three basic texts: (1) *Industrial Instruments for Measurements and Control* by Rhodes, McGraw-Hill, (2) *Instruments and Process Control,* Delmar Publishers, Inc., Albany, N. Y., (3) *Handbook of Measurement and Control,* Instruments Publishing Co., this address.

I have divided my course into 3 basic parts—(1) pickups, (2) amplifiers, (3) recorders, indicators, and controllers. Pickups include sensing elements for pressure, flow, temperature, humidity, chemical composition, pH, radioactivity, etc. Amplifiers include devices for amplification by electronic, hydraulic, and pneumatic methods. The third part includes bridge and potentiometer recorders, control elements, valves, process characteristics, servomechanism theory, etc. I have emphasized analytical instrumentation and electronic circuitry as the newest essentials in the field.

The *Handbook* can be procured only with a subscription to *Instruments.* I feel that all students of instrumentation should be regular readers of *Instruments* if they are to keep abreast of new instruments and new developments. For example, starting in May, *Instruments* will publish ALL the important valve papers delivered at the excellent Control Valve Symposium in New Jersey. Following these will be ALL the papers from the well-known Texas A & M Symposium on Instrumentation for the Process Industries. This is basic information that all instrument men and students should read and study. Thus I recommend strongly that the educational and significant articles in *Instruments* be made a part of the course.

The *Handbook* will be found valuable also for quick teaching and reference on the subjects of Positive Meters, Speed Measurement and Control, Physical-property Testing, Electrical Instruments, Research Instrumentation, and Nucleonics. These subjects should be covered in the course, although most emphasis should be on temperature, pressure, flow, and level measurement and control.

I supplement the three texts with manufacturers' literature. I select the best literature from the list given in *Instruments* each month. You will be surprised at the educational quality of many of these publications, which are free for the asking.

I hope the above will help you, and that you will tell me of the approach you make.

MILTON ARONSON,
Technical Editor

Yes, Herschel Did Invent the Venturi Meter

VENTURI reported so many experiments and published so many drawings that some historians believe he KNEW the relation between differential and flow-rate; and—therefore—originated the Venturi metering PRINCIPLE.

Instruments has always held officially to the view that Herschel invented the Venturi meter. It was just twenty years ago* that a statement to that effect first appeared in our columns. It has appeared several times since then** and now we are pleased to publish the following letter from Charles G. Richardson, an eminent authority on this subject.—MFB

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*April 1932, page 96, in fourth installment of serial "Four Measurement and Control" by M. F. Behar (Jan. '32-Dec. '33).

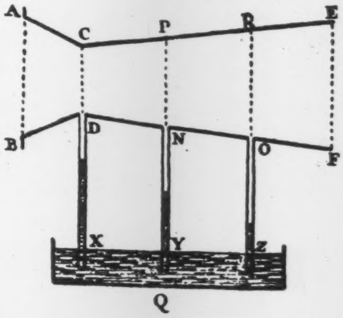
**The last time was in "A Non-mathematical discussion of Flow Measurement" by J. B. McMahon, Apr. 1951, page 470.

Editor *Instruments*:

As one who has been engaged, for some fifty years, in engineering work relating to the measurement of flow of fluids, I would like, briefly, to take exception to a statement by Mr. F. M. Partridge in the February issue. Reference is made to the initial paragraph of his informative article entitled "Fundamentals of Orifice Measurement," reading:

> "The first record of the use of orifices for the measurement of fluids was by Giovanni B. Venturi, an Italian physicist. In 1797 he did some work with various orifices and, later, developed the Venturi Meter which bears his name."

As late as the formation of the American Republic, only a few fundamental laws of hydraulic science had been established. In those closing years of the eighteenth century, Venturi, a noted Italian civil engineer, builder of bridges, and a gifted hydraulician, was spending many hours in the fine physical laboratory which had been built and equipped for him in the University of Modena. Certain fundamentals of hydraulic flow had slowly been established —by daVinci, that the acting head affects the rate; by Torricelli, that the velocity varies as the square root of the head; by Huygens, the numerical value of gravity; by Bernouilli, the equating of the total energy head in every section of a pipe line. Professor Venturi became especially absorbed in penetrating the mysterious manifestations he observed in the flow of water through obstructed and constricted pipes, nozzles, and orifices. Finally, the experiments of several years were collected by him in an important and rare digest entitled (translated): "Experimental Researches on the Principle of the Lateral Communication of Movement in Fluids," illustrated by the author with several pages of excellent sketches. Venturi, however, did not discover any relation between rate of flow and differential pressures caused by an orifice or a cone. For orifice plates, the date of the earliest determination



Continued on page 642

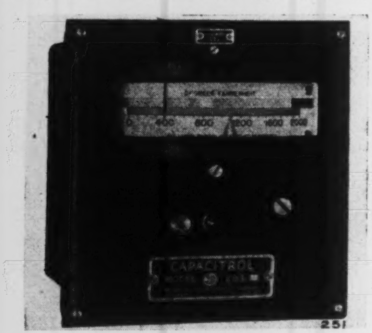
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, computing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 661

Temperature Controller

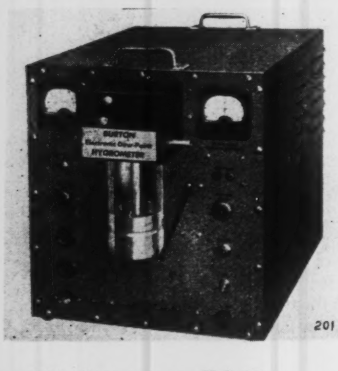
New "Model 293 Capacitrol" indicating pyrometer controller incorporates a built-in unit to provide proportioning control for processing equipment such as ovens, furnaces, kilns, vats, etc. Instrument operates with "Electronic Link" incorporated in maker's "Capacitrol" controllers, but adds new "Line-otrol" feature to automatically minimize "on" and "off" variation of control instrument above and below preset control point, to effect closer control of process variable (temperature, etc.). Controller uses same measuring system and control assembly as its predecessor "Model 292," but with further advantage of being able to compensate for transfer lags.—*Wheelco Instruments Co., 847 W. Harrison St., Chicago 7, Ill.*



Mention No. 501 when filling out card.

Dew-point Hygrometer

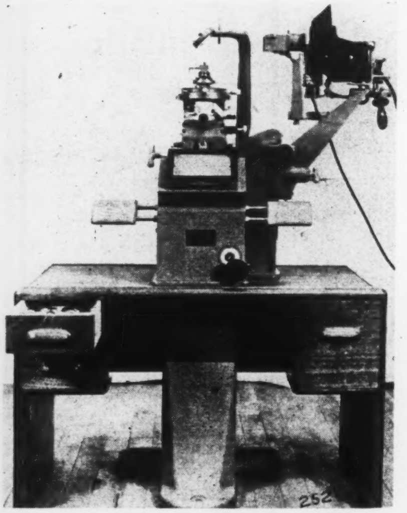
New "Electronic Dew Point Hygrometer" comprises a polished metal mirror and an associated automatic-control system to maintain mirror at dew point temperature; is said to provide a primary laboratory standard for measurement of isobaric condensation temperature. It continuously indicates temperature at which any component of a gas will form a dew. It continuously indicates or controls, through usual thermocouple-based device, concentration of any component whose phase change will fog mirror. Temperature can be any temperature within reach of a liquid air bath. A suitable train of these instruments and associated traps can be used to record concentration of more than one component of a gas.—*Burton Mfg. Co., 11201 W. Pico Blvd., Los Angeles 64, Calif.*



Mention No. 502 when filling out card.

Metallographic Microscope

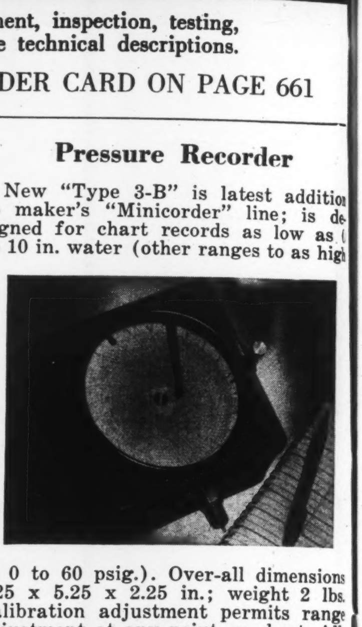
New model of Vickers Projection Microscope, of vertical design, is so rigid that stage can be tapped or camera casting struck without disturbing image, even with high-power optics. Three light sources (carbon arc, "Pointolite" and mercury-vapor lamp) are supplied in any choice of two: one for photography, the other for visual. Facilities include bright-field, dark-field, polarized, phase-contrast, plus graduated rotation for polarizing analyzer, also provision for introduction of compensators and for examination of interference images. Moreover, equipment can be quickly converted to use in macro observation and photography in range from 3X to 39X; also for biological and other transmitted-light applications. Available attachments for micro-hardness, etc. Provision for use of objectives of any make and tube-length. Optical capabilities are said to surpass those of any other European or American equipment.—*R. Y. Ferner Co., 176 W. Adams St., Chicago 3, Ill.*



Mention No. 503 when filling out card.

Pressure Recorder

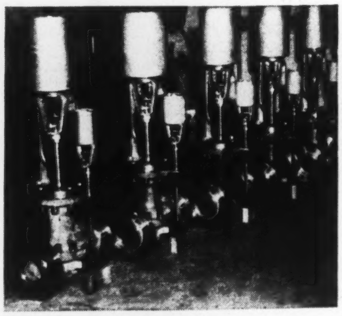
New "Type 3-B" is latest addition to maker's "Minicorder" line; is designed for chart records as low as 0 to 10 in. water (other ranges to as high as 0 to 60 psig.). Over-all dimensions 5.25 x 5.25 x 2.25 in.; weight 2 lbs. Calibration adjustment permits range adjustment at any point on chart. All-metal case is rubber-gasketed for protection from dust, moisture and weather. "Type 3-B" is equipped with a ¼-inch male bottom connection and easily replaces most dial gages.—*The Dickson Co., 7420 Woodlawn Ave., Chicago 19, Ill.*



Mention No. 504 when filling out card.

Control Valves for Extreme Conditions

New "Models 1570 and 1580 Control Valves" are capable of handling a wide variety of materials at extremes of temperature and pressure. These include liquid nitrogen at minus 325 F. and 3000 psi, red fuming nitric acid at room temperatures and superheated steam up to 1000 F. Unique design feature of these single-seated valves is external self-balancing arrangement which provides a balanced valve effect in operation.—*Annin Co., 3500 Union Pacific Avenue, Los Angeles 23, Calif.*



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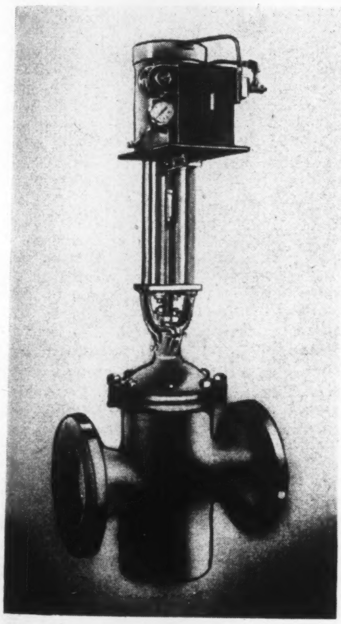
Have you a copy of the Jan. 1928 *Instruments?*

(or, perhaps, of all twelve issues of Vol. 1—Jan.-Dec. 1928?)

Yes, we know that there are unmutilated copies of Vol. 1—and all subsequent volumes—in libraries; but we are after individual owners. Please write to Historical Section, The Instruments Publishing Company, 921 Ridge Avenue, Pittsburgh 12, Penna.

Control Valve Assembly

New complete line of throttling control valves utilize undersigned company's pneumatic cylinder operators on Paul Valve Corp.'s Venturi ball valves. This new combination is said to make it possible to simplify difficult control problems involving corrosive fluids, abrasive materials, high-temperature and high-pressure applications, etc. Since "Cono-cylinder" operator embodies a positioning mechanism, assembly can be used in conjunction with standard pneumatic control instruments for automatic control, or with manual loading stations for remote manual positioning. Valve is available in sizes to 8 in. and in body materials including iron, steel, stainless alloys and nonferrous materials.—*Conoflow Corp., 2100 Arch St., Philadelphia, Pa.*



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The DENSICHRON is supplied complete with a blue-sensitive light probe (or red if specified), five measuring apertures, a cone with 1/8 inch aperture, and metal support for the probe unit. The current consumption is 30 watts. For operation on 115 volts—60 cycle AC only—

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PROVIDES ON-THE-SPOT pH READINGS *ANYWHERE*

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Instrument size:	$3x5\frac{7}{8}x2\frac{1}{2}$ inches
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Weight with accessories:	3 lbs.

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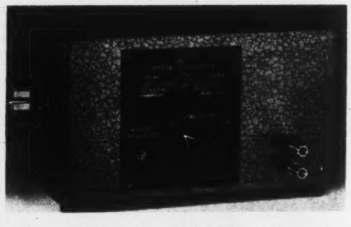
NEW INSTRUMENTS

Frequency Standard

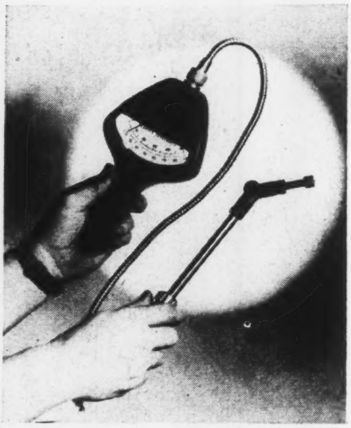
New "Type 1213-A Unit Crystal Oscillator" provides standard frequency harmonics of 1 Mc, 100 kc. and 10 kc. with output frequencies as high as 1000 Mc. Short-period stability (several hours) is about one part per million. Usable 1-Mc. harmonics extend to 1000 Mc. and 100-kc. and 10-kc. harmonics to at least 250 and 25 Mc. respectively. With good receiving equipment, 10-kc. harmonics can be used to 30 Mc. and higher. Crystal frequency can be re-adjusted at any time to agree with standard-frequency transmissions from WWV, or other sources of standard frequencies.—*General Radio Co.,* 275 *Massachusetts Ave., Cambridge* 39, *Mass.*



Mention No. 507 when filling out card.

Hand Pyrometer

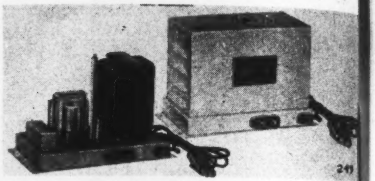
New "Type FH-1" hand pyrometer has two scale ranges (0-500 F. and 0-1500 F.) for measurement of surface, liquid, gas and molten-metal temperatures. Three interchangeable tips: surface tip, immersion tip for liquids and molten metals, and two-pronged contact tip. Accuracy 2.5 percent of full-scale at 80 F. instrument cold-junction temperature.—*General Electric Co., Schenectady, N. Y.*



Mention No. 508 when filling out card.

Constant-current Supply

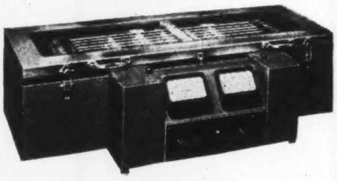
New "Model 50220" constant-current supply provides a steady d-c. source from an a-c. line, is designed primarily for use with potentiometer indicators, recorders and controllers, where automatic standardization is not feasible or where use of batteries is not desirable; also for resistance thermometers strain gages, etc., requiring a constan direct current. Standard unit is designed for a 10-ma. output at 1.4 volts stability well within 0.1 percent. Units for other voltages and currents can b supplied on special order.—*Westo Electrical Instrument Corp.,* 617 *Frelinghuysen Ave., Newark* 5, *N. J.*



Mention No. 509 when filling out card.

Ionograph

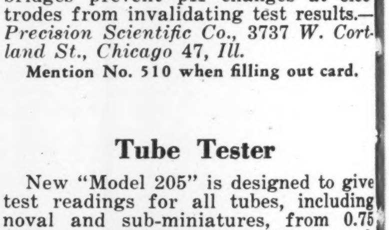
New "Ionograph" separates and identifies materials such as amino acids and proteins. (Ionography is electrophoresis on filter paper; depends on movement of charged particles, both ions and colloids, in an electric field.) Results are in good agreement with classical methods. Instrument can be operated by the average technician; can use seven filter paper strips, of varying length, as well as wide sheets for two-dimensional work. Potential to 2500 volts and current 30 ma. offer fast separation with complete control. Water-saturated helium forms a gas envelope to remove interfering heat effects. Agar bridges prevent pH changes at electrodes from invalidating test results.—*Precision Scientific Co.,* 3737 *W. Cortland St., Chicago* 47, *Ill.*



Mention No. 510 when filling out card.

Tube Tester

New "Model 205" is designed to give test readings for all tubes, including noval and sub-miniatures, from 0.75 volts to 117 filament volts through standard emission method of testing. Tester uses four-position lever-type switches and individual sockets for each



tube base type; is available in either stationary or portable oak cases.—*Electronic Measurements Corp., 280 Lafayette St., New York City.*

Mention No. 511 when filling out card.

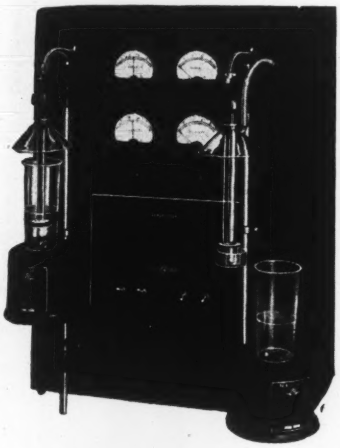
High-energy Miniature Storage Batteries

New "Models 20HR-NS and 60RR-NS are added to maker's line of "Silvercel" storage batteries. Former weighs 15 oz., has normal capacity of 20 amp-hrs.; latter weighs 35 oz., has 60 a-h. normal capacity—both at low discharge rates. High discharge rates are, respectively, 120 amps. for 6 min. and 400 amps for 4 min.—*Yardney Electric Corp., 105 Chambers St., New York 7, N. Y.*

Mention No. 512 when filling out card.

"Mercalyzer"

New "Dual Mercalyzer" for rapid removal of heavy metals from solution by mercury cathode method, permits determination, separation or removal of metals, and quantitative analysis by electro-deposition. It removes up to 5 grams of metal rapidly because of its wide range (0 to 10 volts or amperes per station) and its renewable surface mercury cathode. Dual controls permit two determinations to be run simultaneously and independently. Current is controlled by a single knob, and polarity of electrodes may be reversed for each side. A vacuum connection permits removal of acid fumes. "Mag-Mix" stirrers supply controlled agitation at each position.—*Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.*



Mention No. 513 when filling out card.

Metallographic Polisher

New metallographic polisher has conical disk and belt drive from a ¼-hp. motor to provide polishing-head speeds from 112 to 1160 rpm. at full torque, regardless of specimen pressure on head. Also introduced with polisher is a new 62 x 24 in. metallographic table that will accommodate two polishers, either new large ones, maker's smaller models, or one of each size. Thus, operator may "rough-polish" samples with one polisher, "fine-polish" with another,

Famous Guns

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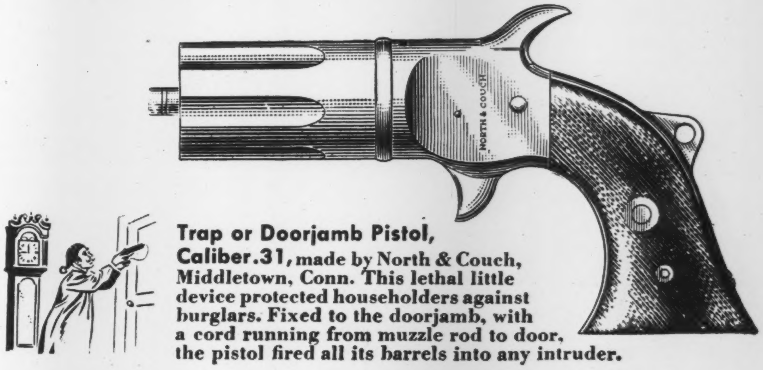
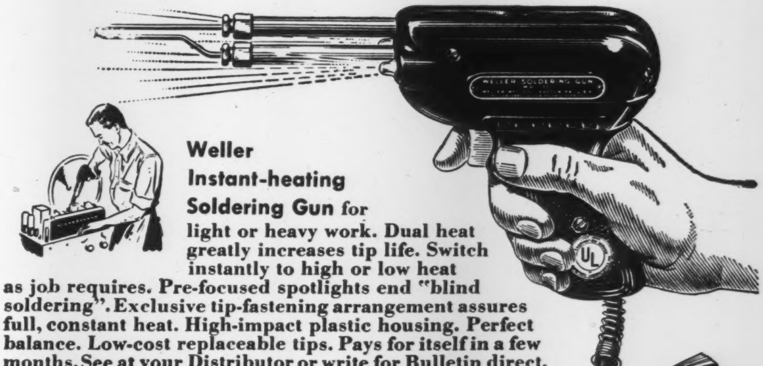
Deringer Percussion Pistol, Model 1843, product of Henry Deringer of Philadelphia. Deringer's large caliber, short barreled pocket pistols were so popular that others imitated them—calling them "derringers". John Wilkes Booth used a Deringer to assassinate Lincoln.



Trap or Doorjamb Pistol, Caliber.31, made by North & Couch, Middletown, Conn. This lethal little device protected householders against burglars. Fixed to the doorjamb, with a cord running from muzzle rod to door, the pistol fired all its barrels into any intruder.



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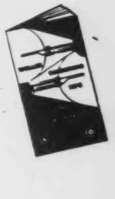

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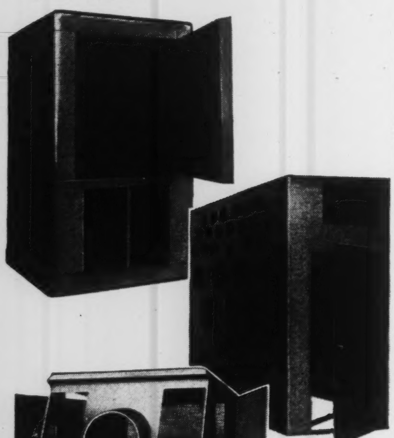

FABRICATORS OF PLATE AND SHEET METALS
LITTLEFORD
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424 E. Pearl St., Cincinnati 2, Ohio

at same table. Nine-inch head is easily removable.—*Fisher Scientific Co.,* 717 *Forbes St., Pittsburgh* 19, *Penna.*

Mention No. 514 when filling out card.

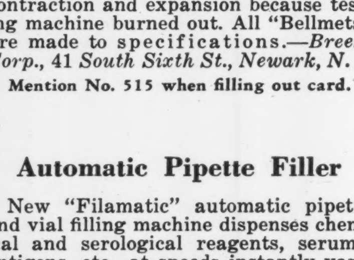
Bellows Units

New "Bellmet" is a new type of welded steel diaphragm bellows with insulated sections, for pressure switches and gages, noise attenuation, etc. It will withstand pressures up to 500 psi. and temperatures of 500 F. Insulating plastic bond is placed either at inner or outer edge of each diaphragm, depending on whether pressure is to be internal or external, so that pressure always serves to reinforce bond. In pressure switch tests, "bellmets" have withstood 1,000 volts without flashover between adjacent sections. Endurance test stopped at 341,000,000 cycles of contraction and expansion because testing machine burned out. All "Bellmets" are made to specifications.—*Breeze Corp.,* 41 *South Sixth St., Newark, N. J.*

Mention No. 515 when filling out card.

Automatic Pipette Filler

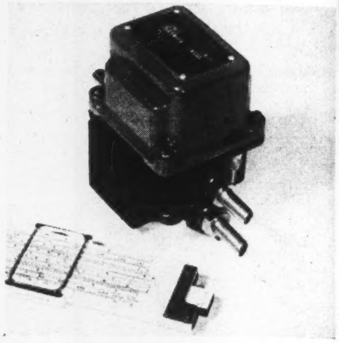
New "Filamatic" automatic pipette and vial filling machine dispenses chemical and serological reagents, serums, antigens, etc., at speeds instantly variable from 10 to 90 deliveries per minute. "Ever-Dri" delivery tip prevents hanging drop. Range is 0.025 cc. to 50 cc. and unit does not have to be re calibrated each time it is used. A liquid contacting parts are made stainless steel. All rotating and movin parts are fitted with "Oilite" self lubricating bearings.—*Scientific Gla Apparatus Co. Inc., Bloomfield, N. J.*



Mention No. 516 when filling out card.

Hydraulic Servovalve

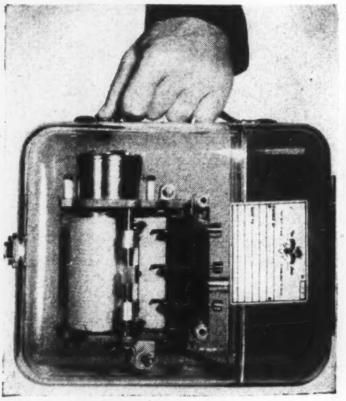
New "Model 3" single-stage 4-wa hydraulic servovalve, for high-performance power servo systems, has ne features including: (1) no change valve characteristics when operating during large temperature variations; (2) free of external leakage; (3) balanced twin-piston construction whereby valve operates smoothly under vibration; (4) both pistons accessible for mechanical actuation, may be utilized for safety limit stops; (5) with maker's manifolding, servovalve may be attached directly to load actuator to produce a complete servomotor free of hydraulic lines from valve to load. Working pressure, 200 to 3000 psi.; max. power to load, approx. 10 hp.—*Midwestern Geophysical Laboratory, Tulsa, Okla.*



Mention No. 517 when filling out card.

Impact Recorder

New model of "Impact-O-Graph" three-way impact recorder has lightweight plastic case; recording bracket affixed to cover which allows for greater freedom of movement by styluses and a more positive mark on processed tape; non-slip tape drive which rigidly con-

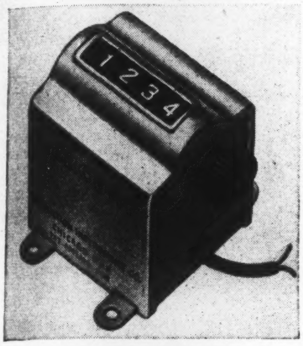


trols one-inch per hour tape travel; and other new features said to improve accuracy and operation.—*Impact-O-Graph Corp., 1900 Euclid Ave., Cleveland 15, Ohio.*

Mention No. 518 when filling out card.

Reset Electric Counter

New small reset type electric counter registers electric impulses at speeds to 600 per minute; may be actuated by switch, relay or photoelectric unit. One complete turn of reset knob resets all number wheels to zero. Furnished for 6, 12, 24, 48, or 115 v. d.c. or 60-cycle a.c.—*Production Instrument Co., 702 W. Jackson Blvd., Chicago 6, Ill.*



Mention No. 519 when filling out card.

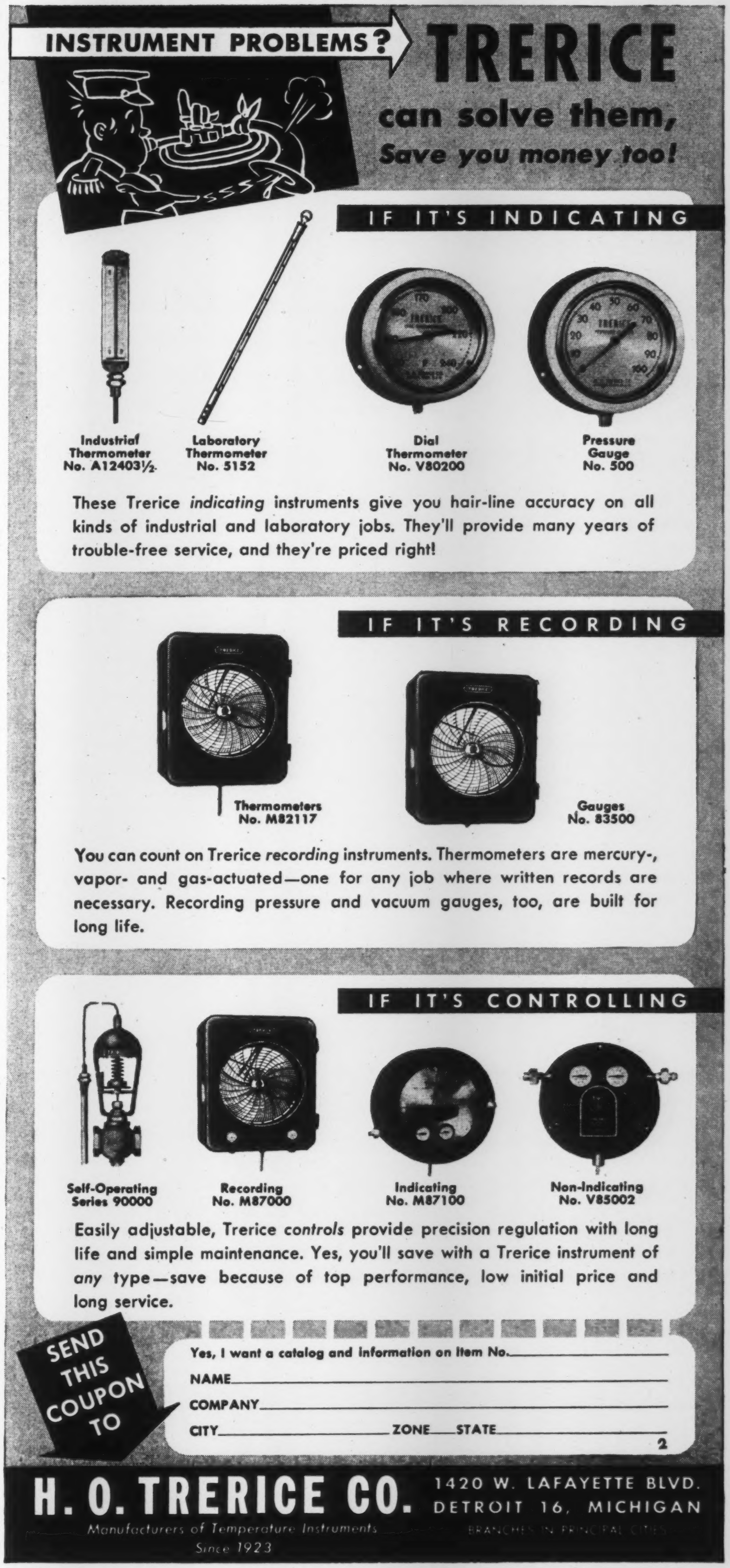
Hand Calculator

New "Curta" Calculator is said to combine portability of a slide rule with speed and accuracy of a large desk calculator. It adds, subtracts, multiplies, divides, figures square roots, factors, cubes and percentages; is as easy to operate as a slide rule; carries to five decimal places and totals to 99 billion. Figures can be checked and re-checked on 3 sets of dials.—*Curta Calculator Co., 5543 S. Ashland Ave., Chicago, Ill.*

Mention No. 520 when filling out card.

Kettle Thermometer

New three-element thermometer with a range of 20 to 220 F., for measuring temperatures in open cooking or cooling vessels, has well-protected mercury-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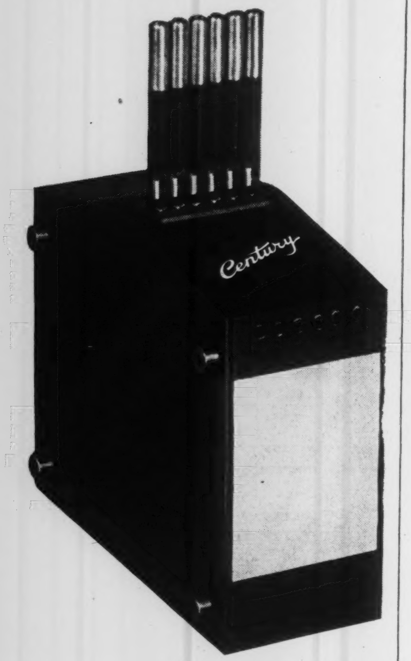

The Century Model 210 Galvanometer has been designed and tested for the utmost in performance under any conditions. The unique small tubular type construction permits their installation in practically any type or make of photographic recording oscillographs. These galvanometers are offered at low cost over a wide range of frequencies and sensitivities to satisfy most recording requirements. For additional information, write for our Catalog No. CGC 206.

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filled glass tube with a yellow backing for easy reading; stainless steel scale with figures and graduations filled with "Pigmaperm"; tube mounting that permanently anchors tube to scale and self-compensates for temperature changes; and cylindrical bulb with large area for quick response. Over-all length 18 in.—*H-B Instrument Co.*, 2633 *Trenton Ave., Philadelphia* 25, *Pa.*

Mention No. 521 when filling out card.

Remote-writing System

New "TelAutograph Instan-Form Telescriber" combines business forms with known principles of Telescriber (handwritten) communication. Business forms filled in on a transmitting "Instan-Form" Telescriber are reproduced immediately (on a similar form) at one or many remotely located Telescribers. Fig. 1 shows transceiver; Fig. 2 shows receiver and "Instan-Forms" automatically ejected so that they may be torn off one-by-one or in groups. Indelible ink makes unauthorized alterations or erasures immediately evident. Instruments will be leased to users.—*TelAutograph Corp.*, 16 *W. 61st St., New York* 23, *N. Y.*

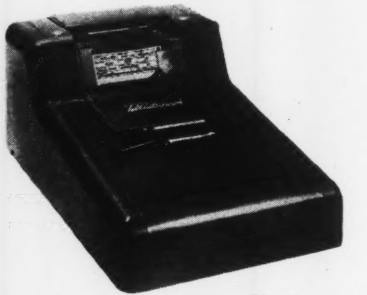

Fig. 1

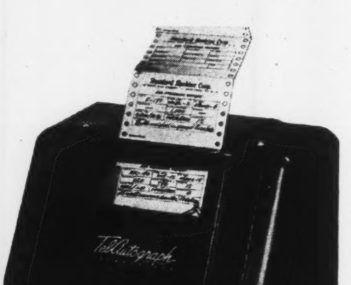

Fig. 2

Mention No. 522 when filling out card.

Fire and Gas Alarm

New fire detector and alarm device gives warning even in initial smoldering stages; will also respond rapidly to temperatures above normal; may be used to warn of presence of combustible gases or vapors in extremely low concentrations. It utilizes increase in electrical resistance of a hot wire with temperature rise due to catalytic combustion of unburned distillation gases. Novel feature is construction of detecting and compensating elements to cancel out extraneous influences. Device is not subject to catalytic poisoning; cannot act to ignite any chance mixture of combustible gases with air in explosive proportions.—*Factory Mutual Engineering Div.*, 184 *High St., Boston* 10, *Mass.*

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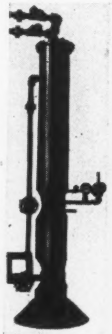


Acid Pump

New "Merc-O-Pump" employs mercury column as liquid mover; is air- or steam-operated. Rate: 3 to 30 gph., variable over entire range by external adjustment. — *Instruments, Inc.*, 122 *N. Madison St., Tulsa* 6, *Okla.*

Mention No. 524 when filling out card.

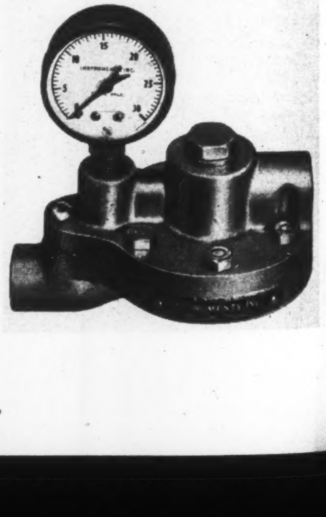
Small Cam Valve

New "No. 636" quarter-inch companion model to maker's line of cam-operated valves has a 3-in. x 3.5-in. base. Lever travel is less than 1 in.—*Ross Operating Valve Co.*, 120 *East Golden Gate, Detroit* 3, *Mich.*

Mention No. 525 when filling out card.

Constant-differential Relay for Purge Service

New "Type 6000" constant-differential relay for purge systems, liquid-level and specific-gravity measurements, maintains constant purge rate regard-



less of downstream pressure changes. Standard flow-rates available: 0.5-1-2-5-25-50 scfh. Pressure rating, 600 psi. —*Instruments, Inc.*, 122 *N. Madison, Tulsa* 6, *Okla.*

Mention No. 526 when filling out card.

VT Volt-ohm-milliammeter

New "Model 601" portable vacuum-tube volt-ohm-milliammeter is battery operated; has six d-c. voltage ranges from 3 to 1,200 v., thirteen megohm input impedance; five a-c. voltage ranges from 3 to 300 v., six megohm input impedance; six ohm ranges from 1 to 100 megohms; and six current ranges from 3 to 1,200 ma.—*American Chronoscope Corp.*, 316 *W. First St., Mount Vernon, N. Y.*

Mention No. 527 when filling out card.

Electrical Indicating Instruments

New ruggedized and hermetically-sealed electrical indicating instruments, manufactured on West Coast, are interchangeable with those of licensor: Marion Electrical Instrument Co. (New Hampshire), in 1.5-in., 2.5-in., 3-5-in. and 4.5-in. sizes, in a-c. and d-c. ranges. —*Phaostron Co.*, 151 *Pasadena Ave., South Pasadena, Calif.*

MILLIAMPERES
PHAOSTRON
RUGGEDIZED
0
.2
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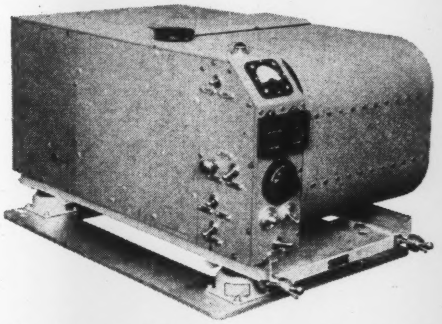
.8
1

Mention No. 528 when filling out card.

Frequency Multiplier

New "Model 134 Clock-Drive Generator" is designed to be energized by a 10-cps input at 5 volts minimum, produces a 115-volt 60-cps output of 5 watts. Developed for continuous fre-

Century INDUSTRIAL
RECORDING OSCILLOGRAPH
FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS

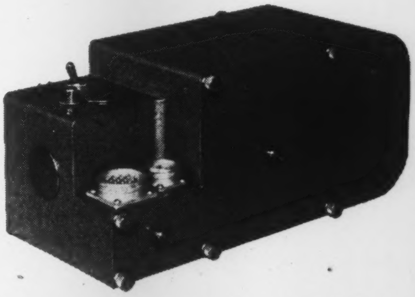


MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:
Size: 20" long, 12½" wide, 8⅞" high.
Weight: 60 pounds.
Number of Recording Channels: 6 to 50.
Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.
Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.
Paper speeds continuously and instantly variable without changing gears or sprockets.
Separate optical system for viewing before or during recording.
Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.
Data numbering at beginning of record.
Footage indicator showing amount of paper remaining in magazine.
Automatic record length control.
Trace identification.
Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:
Size: 5" x 5" x 11".
Weight: 11 pounds.
Cast Aluminum case.
Paper speeds variable ½" to 12" per second.
Detachable daylight loading magazine with a capacity of 3⅝" x 50' paper or film.
2 to 12 individual channels.
Trace identification.
Trace viewing.

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TULSA, OKLAHOMA
1505 Race Street
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EXPORT OFFICE:
149 Broadway, New York

What is 100% Safe?

Anything less than 100% safe is 100% UNsafe.

This fellow's lucky, in a way. He *thought* his safety valves were 100% safe, and because they weren't, they might have killed him. Because those valves were *almost* safe, it's going to cost someone a lot of money.

There's only one way to think of safety—think in terms of 100% or nothing. There's one sure way to *get* 100% safety—specify BalanSeal or FarriSeal Valves.

Why? Because they *can't* stick, plug or corrode. Critical working parts are permanently isolated from any contact whatever with the lading.

Because they're unaffected by back pressures in the discharge manifold due to its own operation or to the opening of other valves in the line.

Because these features make it possible for you to use smaller discharge piping, an economy which often amounts to substantially more than the cost of the valves.

You'll be interested in the engineering of BalanSeal and FarriSeal Valves—design which is rapidly gaining acceptance in hundreds of successful installations.

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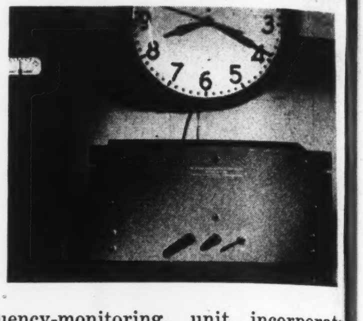
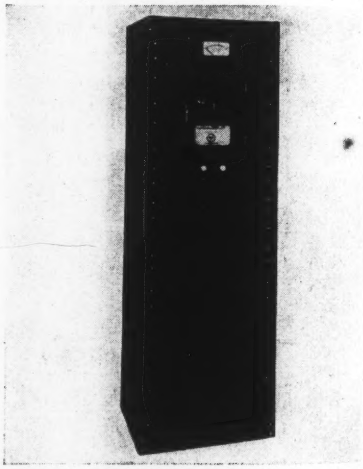


quency-monitoring, unit incorporate its own power supply, operates fro standard 115-volt 50/60-cps power. I basic application, a secondary standar frequency, divided if necessary to 1 cps, is fed to generator. Since generato multiplies by 6, output frequency i 60 cps plus or minus 6 times frequenc error of input. A standard Telechro clock is driven by output signal an compared with primary standard suc as transmissions from WWV. Other applications wherever frequencies are t be precisely multiplied by a factor o six.—*Sierra Electronic Corp.*, 831 *Brittan Ave., San Carlos, Calif.*

Mention No. 529 when filling out card.

High-voltage Breakdown Tester

New "Model PA-5" high-voltag breakdown tester, especially designe to meet ASTM D-149-44 specifications for dielectric strength of electrical in-



sulating materials at commercial power frequencies, comprises suitable transformers and a special gear train and synchronous motor so that test voltage may be increased at a constant rate (e.g. 500 volts per second) until breakdown occurs. Voltage may be varied manually to meet same specification for step-by-step procedure. At breakdown point, power is turned off automatically but instrument continues to indicate breakdown voltage. "PA-5" is available in both 25,000-volt and 50,000-volt models.—*Industrial Instruments, Inc.*, 17 *Pollock Ave., Jersey City* 5, *N. J.*

Mention No. 530 when filling out card.

High-voltage D-c. Power Supply

New "Model 810-P" provides d-c. power at 150 to 1500 v. and 0-5 ma. continuously variable, for applications requiring extreme stability, as where two (or more) CR, GM or PM tubes must be operated at exactly the same voltage. Output voltage varies less than 0.1 volt for full 0 to 5 ma. variation of output current. Output voltage control is a vernier dial with two scales (somewhat like clock hands) providing 1500 divisions. This calibration may be checked by a simple procedure without a Master Standard voltmeter.—*Furst Electronics, 12 S. Jefferson St., Chicago 6, Ill.*

Mention No. 531 when filling out card.

Variable-frequency Power Supply

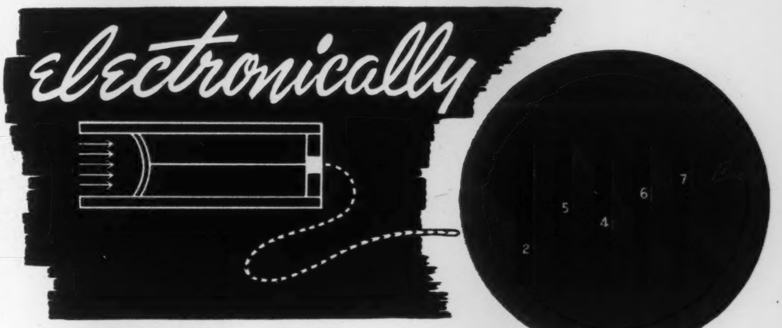
New "Model VS-500" will deliver a regulated output voltage of 115 or 230 volts, plus or minus 3 percent, over a frequency range of 50 to 3000 cps.; is available in 500-watt units. Safety features include an automatic switch that safeguards against accidental high-voltage contact and protective relays and fuses that prevent damage to equipment in event of overloads or accidental shorts.—*Commercial Products Div., Trad Television Corp., Asbury Park, N. J.*

Mention No. 532 when filling out card.

60-cps. Power Supply

New "Model 375" 60-cycle power supply unit provides accurate frequency stabilization (five parts per million per degree Centigrade) and 60 watts of useful power. Input may vary from 50 to 400 cps. and from 90 to 125 volts. Output is adjustable from 0 to 150 volts. On panel: voltage adjust control, 0-150 volt a-c. voltmeter, external os-

Pressure Measurement-



0-50,000 psi
WITH ACCURACIES TO .01%

METHOD: Direct reading digital indication of pressure variation is obtained by using the Berkeley EPUT (Events-Per-Unit-Time) Meter in conjunction with a pressure sensitive frequency generator. The sensing element emits a frequency which varies with pressure. This frequency is transmitted to the EPUT Meter and read directly on an illuminated front panel. The EPUT will count for a precise 1 second period and then read out for 1 second, thus providing independent samplings during alternate 1 second intervals.

ADVANTAGES: Minute variations of fluid pressures may thus be detected with accuracies to .01%. Remote indication can be obtained by telemetering over any desired range, or by cable transmission up to distances of 15,000 feet.

The sensing element is small in size (approx. 1" x 1" x 3") and extremely rugged in construction to permit mounting under practically any field or laboratory condition. This system then provides extreme utility, maximum safety factors, speed, accuracy, and simplicity of operation.

EQUIPMENT: A number of pressure sensing elements are available to accommodate various ranges of pressure from 0 to 50,000 psi. Several different models of the EPUT Meter may be used, depending upon the desired pressure range and the degree of accuracy required. Modifications of this equipment are available to provide extended time base for even greater accuracy and extended range, special mounting, explosion-proof housing, and other special facilities.

SPECIFICATIONS

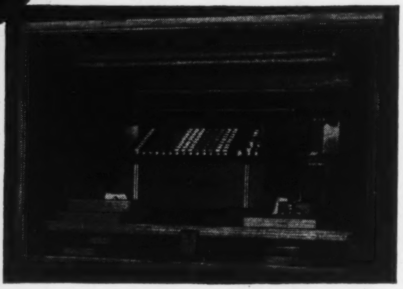
	MODEL 554	MODEL 556
RANGE	20-100,000 cps	20-100,000 cps.
ACCURACY	± 1 cycle	Line voltage stability (approx. 0.1%)
TIME BASE	1 second	1 second
SHORT TERM STABILITY	Standard crystal—1 part in 10^5 Oven crystal—1 part in 10^6	Line voltage stability
POWER REQUIREMENTS	105v.-130v., 60c., 175w.	105v.-130v., 60c., 125w.
INPUT (any wave form)	0.2-50 volts rms (pos.)	0.2-50 volts, rms (pos.)
DISPLAY	Direct reading digital—variable 1-5 seconds	
DIMENSIONS	20¾" x 10½" x 15"	16⅝" x 10¼" x 12⅞"
PANEL	Standard rack 19" x 8¾"	15⅜" x 8¾"
PRICE	$775	$560

This is one of many broad applications wherein Berkeley instruments can provide direct reading digital presentation of information at extremely high orders of accuracy.

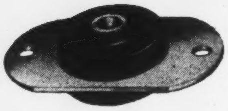
For literature and data, please write for Bulletin 554-I

Berkeley Scientific Corporation
2200 WRIGHT AVENUE • RICHMOND, CALIFORNIA

A Smooth, Safe Ride for SENSITIVE EQUIPMENT.



LORD SHIPPING MOUNTS, *of course!*



Say goodbye to the costly servicing of sensitive equipment at destination — For one user Lord Shipping Mounts cut service and inspection time on overseas shipments from as many as 30 hours to only 4 hours.

Lord Shipping Mounts in your cases protect sensitive mechanisms in transit by cushioning the shocks of rough handling. This protection prevents maladjustment, greatly reducing costly servicing at destination.

If you are paying sizable service and inspection charges on newly shipped machines, stop it now. Lord Engineers will help you. Lord Shipping Mounts provide shock protection far superior to any other packing method . . . and they can be used indefinitely. To cut your shipping costs call or write to—

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ROckwell 9-2151
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CHICAGO 11, ILLINOIS
520 N. Michigan Ave.
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DAYTON 2, OHIO
238 Lafayette Street
Michigan 8871

DETROIT 2, MICHIGAN
7310 Woodward Ave.
TRinity 5-8239

NEW YORK 16, NEW YORK
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PHILADELPHIA 7, PENNSYLVANIA
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LORD BONDED RUBBER

HEADQUARTERS FOR VIBRATION CONTROL MOUNTINGS . . . BONDED RUBBER PARTS

cillator input jack, indicator lamp, stroboscope supply socket, power switch and power fuse.—*Ampex Electric Corp., Redwood City, Calif.*

Mention No. 533 when filling out card.

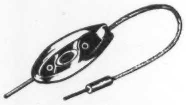
Resistance Limit Bridge

New "Type 1652-A" resistance limit bridge, for production or laboratory use, indicates percentage deviation of unknown resistors. Deviation can be measured from an external standard or from an internal standard adjustable from 1 ohm to 1,111,111 ohms in steps of 0.1 ohm. Maximum deviation is plus or minus 20 percent and accuracy is between 0.2 and 0.5 percent, depending on application.—*General Radio Co.*, 275 *Massachusetts Ave., Cambridge* 39, *Mass.*

Mention No. 534 when filling out card.

Circuit Tester

New "Dandy-Lite" pocket-size circuit tester is designed to test for shorts and grounds on appliances or lines from 90 to 550 v. a.c. and d.c.; utilizes neon glow lamp principle; is complete with two test prods connected to lamp in series; can be used to check automotive cables and circuits, fuses and spark plugs.—*Neo-Lite Mfg. Co.*, 915 *Taylor Ave., Rockford, Illinois.*



Mention No. 535 when filling out card.

TV Marker and Calibrator

New "Model 680 Television R-f. Marker and Crystal-controlled Generator" is a standard (0.05 percent accuracy) for shop, lab and factory. Has

built-in heterodyne detector and magic-eye tube zero-beat indicator. Signal generator ranges: 53-89 Mc. and 174-217 Mc. on fundamentals and to 868 Mc. on harmonics.—*The Hickok Electrical Instrument Co.,* 10519 *Dupont Ave., Cleveland* 8, *Ohio.*

Mention No. 536 when filling out card.

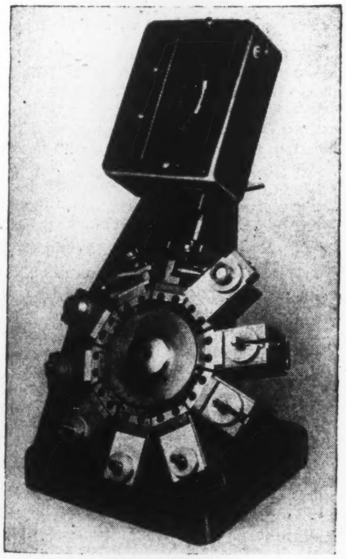
Pocket-size Volt-ammeter

New "Amprobe 600" is latest addition to maker's line of snap-around volt-ammeters. It combines six ammeter ranges and three voltmeter ranges: 0-15/30/60/150/300/600 amps. a.c., and 0-150/300/600 volts a.c.—*Pyramid Instrument Corp., Lynbrook, N. Y.*

Mention No. 537 when filling out card.

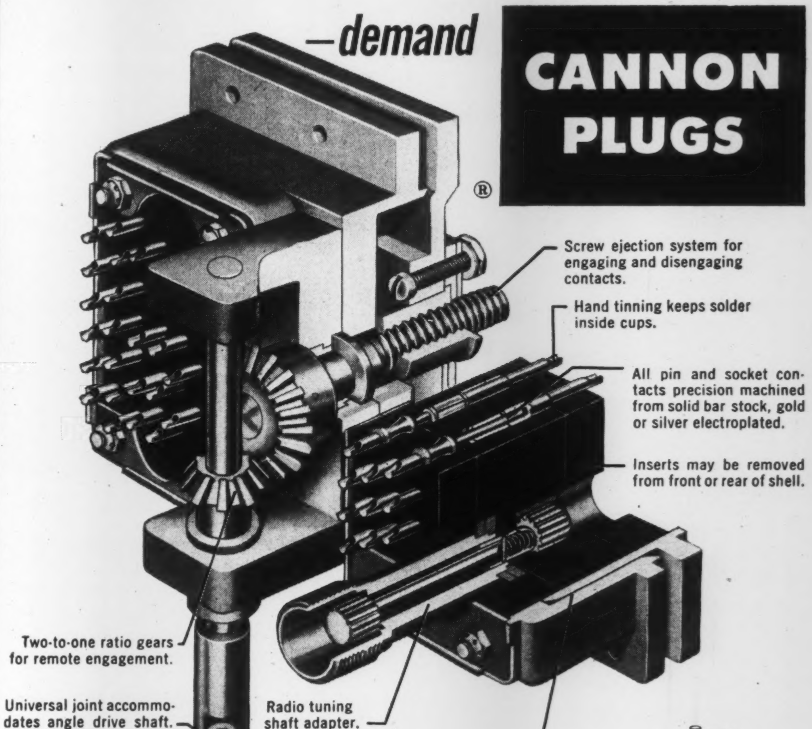
Ten-station Automatic Gaging Machine

New "Sigma Turret Mechanical Comparator" differs from conventional multi-station automatic inspectors in that it has only one measuring head. This measuring instrument—accurate to 4 microinches— is stationary; a rotating turret brings to it a series of up to ten gaging fixtures. Each fixture has a tongue which transfers result of gaging



Here's why those in the know —demand

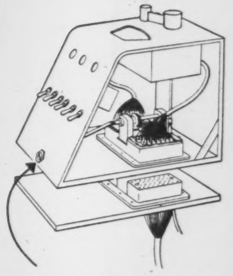
CANNON PLUGS ®


Screw ejection system for engaging and disengaging contacts.
Hand tinning keeps solder inside cups.
All pin and socket contacts precision machined from solid bar stock, gold or silver electroplated.
Inserts may be removed from front or rear of shell.
Two-to-one ratio gears for remote engagement.
Universal joint accommodates angle drive shaft.
Radio tuning shaft adapter.
Tapered shells automatically center contacts for engagement.

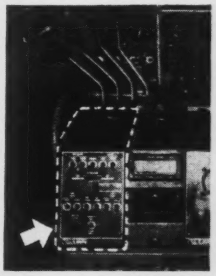
This highly specialized DPD2 Cannon Plug, a member of the DP Series, has its principal use in aircraft instrument panels and remote radio control equipment. But, like many other Cannon Plugs, it has found its way into other fields where the highest quality is needed and where the value of long, trouble-free performance is recognized.

Originally this 2-gang connector was designed to assist in the standardization of radio and instrument assemblies so that such equipment might be interchanged between similar aircraft. It allows for compact design in close quarters with access from the front only. This type of application and variations of the fittings are shown at right. Any Cannon DPD insert may be placed within the shell, with or without tuning shaft, coax, twinax, large or small contacts, provided the separation forces of both halves are similar.

This plug typifies the close attention to important detail that distinguishes every Cannon Plug—the world's most extensive line. If you are looking for real value, regardless of the field you work in, your best bet is Cannon.



Connector is separated by turning slotted shaft here. Complete unit may then be removed from pedestal, shown below.



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Since 1915

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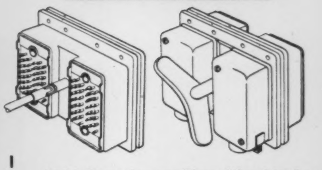
LOS ANGELES 31, CALIFORNIA

Factories in Los Angeles, Toronto, New Haven. Representatives in principal cities. Address inquiries to Cannon Electric Company, Dept. E-180 P.O. Box 75, Lincoln Heights Station, Los Angeles 31, California.



(Left) Same Cannon Plug without tuning shaft. Straight drive instead of 90° gear. (Right) Similar DPD2 with Dzus wing nut extraction method and junction shells. There are several other variations. Write for details.

Presenting THE NEW DeJUR RUGGEDIZED Instruments

RUGGEDIZED
DC
ACV
OHMS

DeJUR Amsco Corporation announces the addition of the new Series R-210 and R-310 Ruggedized Instruments. In meeting government specification MIL-M-10304, DeJUR has incorporated features heretofore unobtainable in ruggedized instruments. They have been designed to meet and even surpass the exhaustive tests required by the armed services. They perform perfectly under the severest service conditions that would destroy conventional instruments.

2½" AND 3½"

RUGGEDIZED D. C. INSTRUMENTS

MODEL R-210 MODEL R-310

MEETS MIL-M-10304

- Mechanism suspended by internal live rubber ring mounts for maximum shock displacement and protection.
- External live rubber grommet for shock mounting with interlocking part of front bezel eliminates glass breakage and bezel distortion.
- Water-tight seal to panel provided by rubber grommet.
- Glass to metal seal for perfect hermetic sealing.
- Drawn steel case with heavy cadmium plate provides high degree of magnetic shielding.
- High-grade fusion seals for terminals and window glass withstand thermal shock of extreme temperature changes.
- Rugged glass-to-metal seal terminals withstand a 3000 volt breakdown test under extreme humidity conditions.
- Entire mechanism has complete ruggedized construction for high shock and vibration resistance.

Ranges from 250 microamperes to 8 milliamperes D.C. available for immediate delivery in 2½" size. Other ranges in 2½" and 3½" being submitted for government approval.

A request on company letterhead to Dept. M-N will put you on our mailing list, and bring you BULLETIN 200N.

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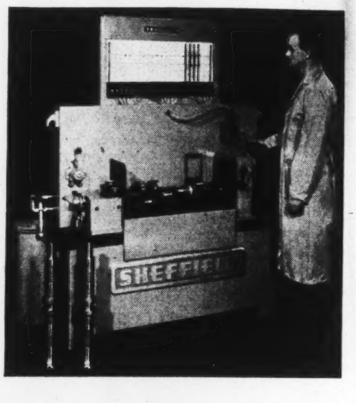
45-01 NORTHERN BOULEVARD, L. I. C. 1, N. Y.
• CAMERAS • PROJECTORS • ENLARGERS • EXPOSURE METERS •

operation to stationary indicating instrument. Four standard fixtures permit gaging: OD, ID, length, depth. Fixture capacity is approx. 2 in. A color code, showing operator what tolerance limits are for each station, is said to make it unnecessary to give consideration to gage mfg. tolerance, wear allowance or error of feel. Machine is made by Sigma Instrument Co., Letchworth, England.—*Cosa Corp.,* 405 *Lexington Ave., New York* 17, *N. Y.*

Mention No. 538 when filling out card.

Automatic Crankshaft Inspector

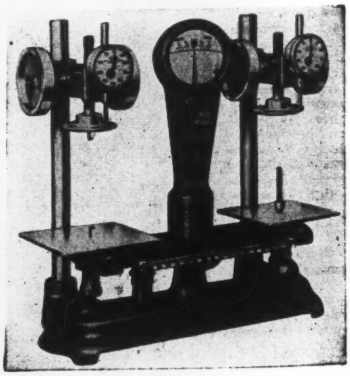
New machine for multiple gaging of critical dimensions on an automotive crankshaft checks main bearings for size and taper; pilot hole diameters; flange diameters and runout; thrust bearing faces; key-way locations, etc.; makes possible 100 percent inspection of crankshaft. Up to 34 or more dimensions can be gaged and read simultaneously by a glance at "Airechart" formed by float positions in "Precisionaire" columns.—*The Sheffield Corp., Dayton* 1, *Ohio.*



Mention No. 539 when filling out card.

Spring Tester

New coil-spring testing machine provides a standard method of testing for manufacturer and for ultimate user; can be used by relatively inexperienced personnel, for determining spring gradient, for a check of free height in relation to load, and for effect of wire size

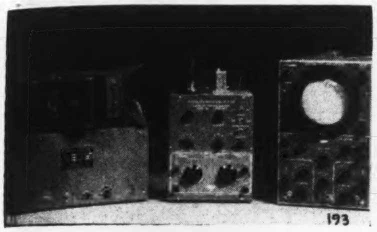


on load. Tester is essentially an equal-beam weighing scale mounted on a base with a sponge rubber pad underneath to minimize vibration, and with built-in dashpot to dampen oscillation of pointer and pans. Behind weighing pans are spring-length measuring devices.—*Torrington Mfg. Co., Torrington, Conn.*

Mention No. 540 when filling out card.

Cam-shaft and Profile Inspection Tester

New "Type 126 Electronic Cam Shaft and Profile Inspection Tester," for use in automotive and mechanical industries, enables measurements to be made to 0.0001 inch. Contour presentation is displayed on c-r. tube; and curves of velocity, displacement, or acceleration may be obtained. Cam pushes a rod-shaped permanent magnet back and forth inside a pickup coil which generates a voltage proportional to velocity, and this voltage is integrated to obtain displacement, or differentiated to get acceleration. System may also be used directly on engine to study valve motion at high speeds.—*Sterling Instruments Co.,* 13331 *Linwood Ave., Detroit* 6, *Mich.*



Mention No. 541 when filling out card.

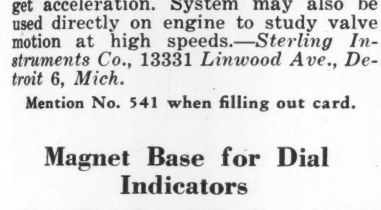
Magnet Base for Dial Indicators

New "Dial Test Set" with magnetic base holder attaches with a 100-lb. pull to flat or curved surfaces. Feature is a finger-tip release for removing (or positioning) without jarring dial indicator.—*Dept. AC, Chicago Dial Indicator Co.,* 180 *N. Wacker Drive, Chicago, Ill.*

Mention No. 542 when filling out card.

Proportional Counter Converter

New "Model PCC-12" converts any scaler with a high voltage range of 800 to 2000 v. to a reliable proportional counter. NMC standard amplifier and pulse height selector, used for proportional counting, is included. "PCC-12"



Pacing Relay Progress

"UPSTAIRS" as well as down

Recent additions to the broad array of Struthers-Dunn relay types play vital defense roles in a wide variety of applications ranging from 70,000 feet in the air to below the ocean surface. Important S-D design and engineering advances materially improve relay performance under shock, vibration, ambients to 200°C., high humidity and other adverse conditions encountered in military operations.

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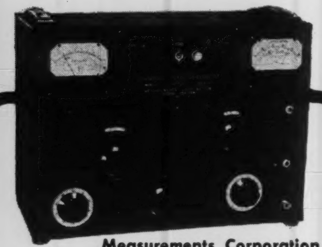
OVER 17,000 COPIES NOW IN USE
"RELAY ENGINEERING," the famous 640-page handbook brings you full benefit of Struthers-Dunn's experience in producing thousands of relay types. The ideal guide to modern relay selection, use, maintenance and circuitry. Price $3.00.



Measurements Corporation
MODEL 82

STANDARD SIGNAL GENERATOR

20 Cycles to 50 Mc.

FREQUENCY RANGE: 20 cycles to 200 Kc. in four ranges. 80 Kc. to 50 Mc. in seven ranges.

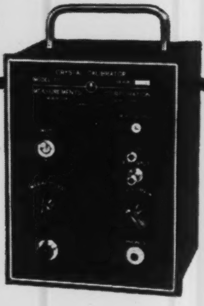
OUTPUT VOLTAGE: 0 to 50 volts across 7500 ohms from 20 cycles to 200 Kc. 0.1 microvolt to 1 volt across 50 ohms over most of range from 80 Kc. to 50 Mc.

MODULATION: Continuously variable 0 to 50% from 20 cycles to 20 Kc.

POWER SUPPLY: 117 volts, 50/60 cycles. 75 watts.

DIMENSIONS: 15" x 19" x 12". Weight, 50 lbs.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY



Measurements Corporation

MODEL 111

CRYSTAL CALIBRATOR

For The Frequency Calibration Of Equipment In The Range Of

250 Kc. to 1000 Mc.

(To within .25 Mc.)

Frequency Accuracy: ±0.002%

The Model 111 provides a test signal of crystal-controlled frequency and has a self-contained detector of 2 microwatts sensitivity.

For calibration and frequency checking of signal generators, transmitters, receivers, grid-dip meters, etc.

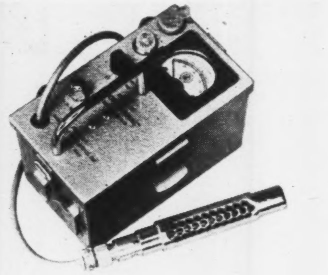
MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

is designed for use with standard beta-gamma types of scaling units; handles samples with diameters up to 8 in. and as deep as 1 in. Chamber discriminates between alphas and betas by high voltage setting only. It counts betas in presence of alphas, and alphas in presence of betas. Since counter is windowless, no absorption of energy occurs and lowest-energy rays are counted with full efficiency. All chamber parts are interchangeable so that standby contaminable parts may be stocked for immediate replacement.—*Nuclear Measurement Corp., 3339 Central Ave., Indianapolis 5, Ind.*

Mention No. 543 when filling out card.

Geiger Counter for CD

New "Model 107 Professional" Geiger counter is designed primarily for civilian defense; has a three-range indicator, a neon flasher and earphones.



Ranges: 0.2, 2.0 and 20 milliroentgens per hour full-scale; accuracy within 10 percent on all ranges. A calibrated radioactive sample makes it possible to calibrate instrument in the field. Directional probe has a sliding shield for discriminating between betas and gammas. Weight is about 5 lbs.—*Precision Radiation Instruments, 4113 W. Jefferson Blvd., Los Angeles 16, Calif.*

Mention No. 544 when filling out card.

Radiation Dosimeter

New radiation dosimeter is wristwatch-size, waterproof, shockproof and unaffected by extremes of heat or cold; has for indicating element a tiny piece of special glass which, when exposed to atomic radiation, becomes fluorescent under ultraviolet light. User keeps dosimeter on his person. Whenever there has been danger of harmful radiation, he checks his dosimeter in an "electric-eye reader" at his headquarters. This instrument gives a reading, in roentgens, of total radiation user has received since he has been carrying dosimeter.—*Polaroid Corp., Cambridge 39, Mass.*

Mention No. 545 when filling out card.

Radioactivity Detector Kit

New "Super Scout" radioactivity detector in kit form is easily assembled in one evening "by anyone who is mechanically inclined." It detects presence of gamma rays, medium-to-high energy

Need Help in a Hurry?

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- To Close Tolerances
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1-High Speed, Automatic Screw Machines . . . Multiple & Single Spindle

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During the last war Steinen produced, and today Steinen is producing in larger volume than ever before—parts, sub- and complete assemblies for many of the leading manufacturers of aircraft, automotive, electronic, electrical, household appliances, instruments, machinery and metal products, oil burner nozzles and components, toys and novelties. You, too, can depend on their judgment as to Steinen quality, production economy and service.

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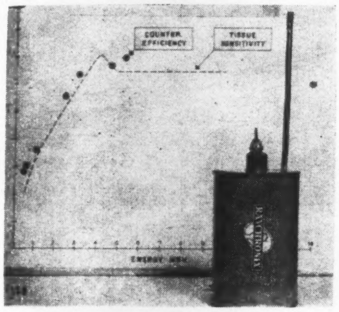
Scout
Scout

beta rays, as well as cosmic and x-rays. Clicks heard in headphones and flashes of neon bulb increases markedly in frequency as radiactive source is approached. To simplify assembly, some parts are supplied pre-mounted. Any 2000-ohm headphones may be used for audible detection.—*Allied Radio Corp., 833 West Jackson Blvd., Chicago 7, Ill.*

Mention No. 546 when filling out card.

Neutron Counter

New "Raychronix F-1" fast neutron proportional counter, with response proportional to neutron sensitivity of human tissue over energy range of 0.2 to 10 Mev., derives its characteristics from a combination of high- and low-energy polyethylene radiators, hydrogenous gas filling, and precise geometrical configuration. Axial response is twice the lateral response. Length is 3.12 in., dia. is 2 in.—*Radioactive Products, Inc., 443 W. Congress, Detroit 26, Mich.*



Mention No. 547 when filling out card.

Illuminated Magnifier

New "Model 66SV" portable high intensity fluorescent fixture, designed primarily for industrial inspection, is equipped with either a 2- or 4-power

OUTSTANDING CARRIER FREQUENCY STABILITY

...in this new
Bendix-Pacific
crystal-controlled
TELEMETERING TRANSMITTER

Bendix-Pacific has developed a new subminiature airborne telemetering transmitter offering outstanding carrier frequency stability under extremes of temperature, vibration and acceleration. This new unit is a crystal-controlled, phase-modulated, VHF transmitter.

The Bendix **TXV-11 VHF** Telemetering Transmitter, now in production, meets the following specifications:

Temperature Stability: Carrier drift less than ± .02% from —40° C. to +70° C.

Vibration: Maximum noise is less than an equivalent carrier deviation of ± 0.25 kc when subject to a sinusoidal vibration 20 to 300 cps at 10 g in any plane.

Acceleration Error: Negligible to 75 g along 3 major axes.

Power Output: 2 watts (nominal)

Output Impedance: 52 ohms (nominal)

Modulator Input Impedance: 470 K ohms and 60 mmf.

Modulation Index (b): 1.8 at .3 v rms.

Distortion: Less than 1.5% total harmonic distortion for any frequency between 2300 cps and 70 kc at a modulation index of 1.8.

Heater Supply: 6.3 v ± 10% at 1.2 A

Plate Supply: 200 v at 60 ma.

Screen Supply: 150 v at 15 ma.

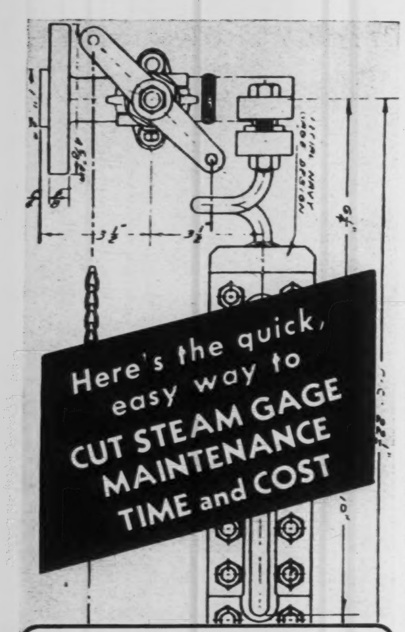
Size: $2\frac{13}{16}$ x $3\frac{5}{8}$ x $1\frac{11}{16}$

Weight: 0.9 lb.

Write the factory for complete engineering data

Bendix
Pacific Division
Bendix Aviation Corporation
NORTH HOLLYWOOD, CALIF.

TO MEASURE..TO WARN..TO INDICATE..AT A DISTANCE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CUT STEAM GAGE MAINTENANCE TIME and COST

Install Labor-Saving JERGUSON STEAM GAGE UNITS

. . . with gage and valves furnished as integral unit . . . without gage connection stuffing boxes or end stems.

JERGUSON Steam Gage Units, with gage and valves fabricated as a complete working unit will help you eliminate a lot of your maintenance time and troubles.

Especially designed to cut maintenance time, these complete units have no gage connection stuffing boxes to take care of and no end stems to cut or wire draw.

Gages and valves are an integral unit and have special expansion coils to take care of expansion and contraction. Transparent gage may be rotated to any desired angle: chambers and covers are forged steel; glasses are mica protected against erosion. Available in various models for required visible glass and W.S.P.

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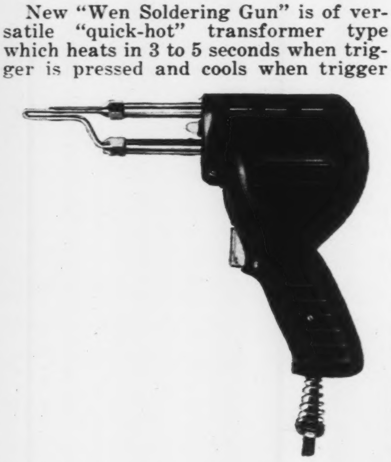
lens, 2 x 4 inches. Lens holder is hinged, offering inspector choice of using light with or without lens. Lens also acts as chip shield when in use. "Model 66SV" is factory equipped with either a heavy portable cast base or for permanent installation.—*Stocker & Yale, Green St., Marblehead, Mass.*

Mention No. 548 when filling out card.

Soldering Gun

New "Wen Soldering Gun" is of versatile "quick-hot" transformer type which heats in 3 to 5 seconds when trigger is pressed and cools when trigger is released. Built-in spot light illuminates work. Long tip reaches spots otherwise inaccessible. Gun operates on 110-120 v. a.c., consumes 250 watts.—*Wen Products, Inc., 5806 Northwest Highway, Chicago 31, Ill.*



Mention No. 549 when filling out card.

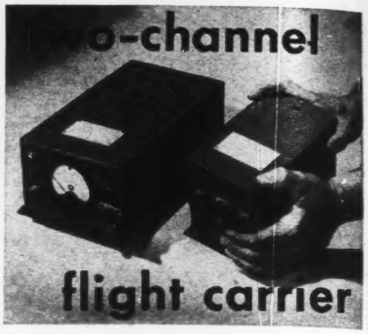
Shop Spot-light

New "Miti-Mite" directs light precisely where wanted while working on machine shop equipment, etc. Its permanent-magnet base holds on with a 50-lb. pull to flat or curved ferrous metal surface. To it is attached, by means of a ball stem, a bracket assembly having a socket clip holding an electric socket to accommodate a 25 or 40-watt bulb which, together with shield, has a length of 4.75 in. Switch is on light socket. Magnetic base is concave for mounting on rounded surface such as a shaft or pipe.—*Enco Mfg. Co., 4522 W. Fullerton Ave., Chicago, Ill.*

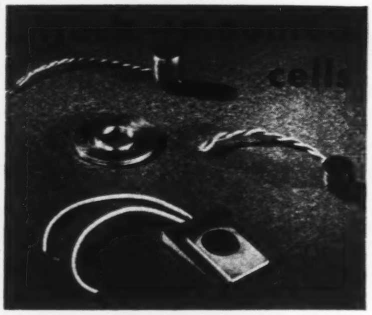
Mention No. 550 when filling out card.

Cutting Plier

New "No. 101 Plier-Snip" is 4.5 in. long, will find applications in fine-wire cutting or thin-metal snipping; fea-



For TRUE dynamic air-pressure measurements of flutter, buffeting, and gust loads. Automatic-zero circuit corrects for static-temperature and pressure variations, gives real unattended operation. High gain with low noise combine sensitivity with clean hash-free oscillograph records.



Flush-mounted pressure cells in a wide variety of forms and dynamic ranges give TRUE phase and amplitude measurements. Insensitive to vibration and acceleration. Diameters as small as 3/8 in. Mount as close as 1/2 in. from trailing edge. No error-inducing connecting tubes or instrument volume. Send for full information on your particular problem.

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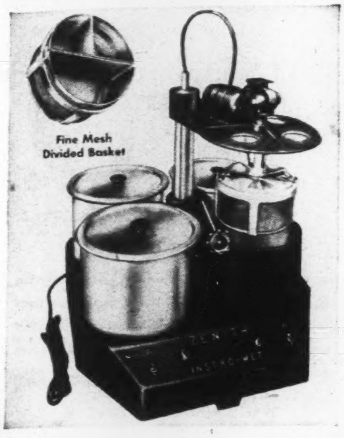
San Carlos, California

tures an extended throat for greater reach in cramped quarters without reduction in leverage. Cutting edges are hand-honed.—*Utica Drop Forge & Tool Corp., 2500 Whitesboro St., Utica 4, N. Y.*

Mention No. 551 when filling out card.

Instrument Cleaning Machine

New "Instro-Met," designed specifically for cleaning instruments, is said to embody "many new and revolutionary improvements," including: (1) three clear-view windows on motor support for checking while in operation; (2) spun aluminum 4-gal. tanks and covers; (3) cast aluminum basket with 33 percent more capacity, has three Monel mesh removable compartments; (4) automatic centering over tanks and dryer; (5) basket lowers only when in proper position; (6) "Finger-tip" control enables female operator to work machine without fatigue.—*Zenith Mfg. & Chemical Corp., 52 Beekman St., New York 38, N. Y.*



Mention No. 552 when filling out card.

Steam-cleaning Compound

New "Magnus 72" contains no alkaline salts, is nonconducting, and is safe where electric circuits are involved. Other advantages: neutral in reaction, will not streak good paint, no hazards of skin contact, generates no objectionable fumes, and can be used indoors.—*Magnus Chemical Co., Inc., South Ave., Garwood, N. J.*

Mention No. 553 when filling out card.

Glass-blower's Torch

New glass-blower's hand torch, originally designed for removing and sealing off glass tubes in a vacuum system,

CONTROLLED
VOLUME
PUMPING

OF "HARD-
TO-HANDLE"
CHEMICALS

...AND NO
STUFFING
BOX

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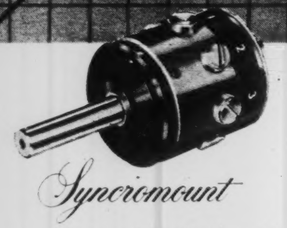
PULSAFEEDER

Concentrated sulphuric acid, sodium sulphite, filter aid slurries, liquid caustic, any water-treating chemical . . . hold no fears for the Lapp Pulsafeeder. It's the positive-displacement metering pump with the hydraulically-balanced diaphragm —no stuffing box or running seal. Pumps against pressures up to 2,000 lbs., at constant pumping speed—variable flow results from variation only in piston stroke length, controlled by instrument air pressure responding to flow-orifice meter, flow-positive meter, pH control, flow variable-pH variable in combination, or other control instruments.

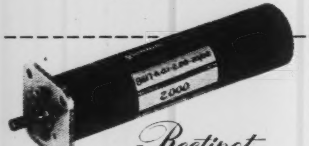
NEW BULLETIN AVAILABLE. Write for Bulletin 300, just issued. 24 pages of description, specifications, typical applications, flow charts. Lapp Insulator Co., Inc., Process Equipment Division, 570 Maple Street, Le Roy, N. Y.

potentiometers



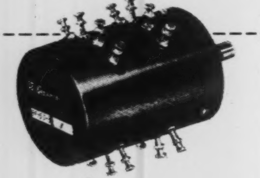
Syncromount

Linear and functional output, rugged construction, ball bearings, small size, low torque, syncro-type mount.



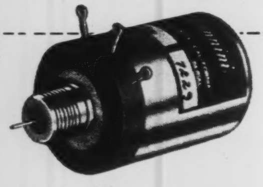
Rectipot

Push-pull motion, linear and functional output, high resolution, rectilinear potentiometer.



Gangpot

Functional and linear outputs, coils independently adjustable, variety of flexible assemblies.



Microtorque

Linear output, minimum torque, potentiometer and selsyn outputs, most ultra sensitive of them all.

These potentiometers are available in a variety of resistance values and circuits. For details on these and other fine instruments, write:

G. M. GIANNINI & CO., INC.
Pasadena 1, Calif.

Giannini

has a U-shaped fork carrying three grid-type, interchangeable, fish-tail burners, placed 90 degrees apart so that flames converge at midpoint.—*Research Vacuum Supply Co.*, 3434 *W. Montrose Ave., Chicago* 18, *Ill.*

Mention No. 554 when filling out card.

Emergency Light

New "GS No. 16" automatic emergency light plugs into any 110-volt a-c. outlet (d-c. available). In event of interruption in regular lighting circuit, it comes on instantly from power supplied by dry battery.—*General Scientific Equipment Co.,* 2700 *W. Huntingdon St., Phila.* 32, *Pa.*

Mention No. 555 when filling out card.

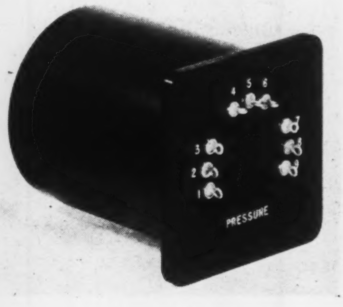
Desiccator

New "Alumaloy" desiccator cannot be damaged by bumping or dropping; weighs a fraction of a comparable glass desiccator, has 4.5-in. square cast aluminum alloy body and cover. Ground joint seal assures air tight closure.—*Laboratory Industries, Inc.,* 4710 *W. North Ave., Chicago* 39, *Ill.*

Mention No. 556 when filling out card.

Pressure Pickups

New "Series 411 Pressure Transducers" utilize diaphragms to convert pressure into resistance-ratio or voltage-ratio. Available ranges up to 30



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Shockstop!

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Protects against Pulsation and Shock!

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For the first time, a successful means of eliminating the effect of pulsation and shock on pressure gage mechanisms has been developed which DOES NOT introduce an orifice or restriction in the pressure connection.

It Can't Plug

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A widely known electrical manufacturer CHEMICALLY CLEANS 1 UNIT EVERY 8.3 SECONDS. Costly reprocessing due to dirty units is eliminated. Production lines operate at better efficiency peaks.

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The ENG-SOL Method may be the answer to your precision instruments cleaning problem. Our bulletin "Precision Cleaning" describes this new high-velocity compressed air method of cleaning. Write for it today.

PASSAIC ANALYTICAL LABORATORIES, Inc.
228 Aycrigg Ave. Passaic, N. J.

psia., 30 psig., and plus-or-minus 15 psi. differential. Units have one, two or three potential-dividing resistors, with or without center or other taps, with either linear or special-function outputs. Standard units (2000 ohms) carry 10 milliamps, weigh less than 0.7 lb. "Series 811" (not illustrated) take pressures up to 6000 psi.—*Colvin Labs., 12 Court St., Morristown, N. J.*

Mention No. 557 when filling out card.

Anti-hunting Component for A-c. Servomechanisms

New "Twin-T Servo Stabilizer" for a-c. servo systems contains a variable damping adjustment, is equipped with cathode followers for input and output, and plugs into an octal socket. It contains a phase shifting network to compensate for lag caused by motors or other inertial elements. It overcomes hunting while maintaining fastest possible response time.—*Kalbfell Labs, Inc., P. O. Box 1578, San Diego 10, Calif.*

KAY-LAB
TWIN-T
SERVO
STABILIZER

Mention No. 558 when filling out card.

Sealed Relays and Stepping Switch

New series of hermetically-sealed enclosures, containing a group of relays or a stepping switch, provide an atmosphere of dry, inert gas. Entire relay circuits with up to six relays can now be enclosed in one hermetically-sealed unit (Fig. 1). Individual relays

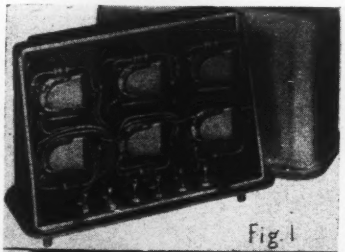

Fig. 1

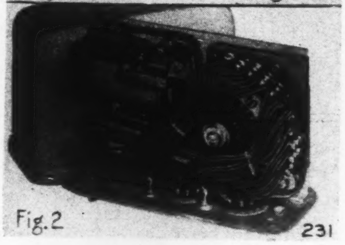

Fig. 2

SAY "GOODBYE"

TO BIG PROBLEMS WITH SMALL PARTS

INVESTIGATE

LEVIN®

PRECISION JEWELER'S LATHES, ACCESSORIES AND MICRO-DRILL PRESSES

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An extremely sensitive drill press for very small drills down to .002". Drills held in accurate collets to minimize deviation. Spindle run-out less than .0001". Finger tip control enables operator to feel progress of drill.

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TANK°METER
FOR MEASURING TANK CONTENTS ANY DISTANCE AWAY

ANY LIQUID

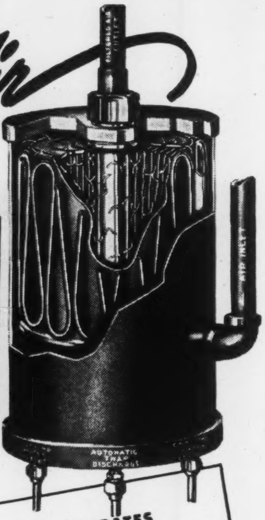
HYDROSTATIC GAUGES
FOR ALL PURPOSES

PRESSURE • VACUUM • DRAFT
DEPTH & ABSOLUTE PRESSURE
BAROMETRIC PRESSURE
DIFFERENTIAL PRESSURE
SEND FOR BULLETINS

UEHLING INSTRUMENT CO. 470 GETTY AVE., PATERSON, N. J.

NOW ··Clean, Dry Compressed Air —for Operating Instruments!

The NEW Model B-30 HANKISON Condensifilter



For maximum protection of air-operated instruments against oil, water, sludge and foreign materials, the New Hankison Model B-30 Condensifilter features a dehydrating device—a mechanical filter—and a self-purging trap in a single compact unit. Only 15" high and 9" in diameter, this unit will clean and dry compressed air at the rate of 30 c.f.m. at 100 psi. Larger models available for greater capacities.

To add long life and trouble-free service to your air-operated instruments—specify B-30 Condensifilters for your requirements.

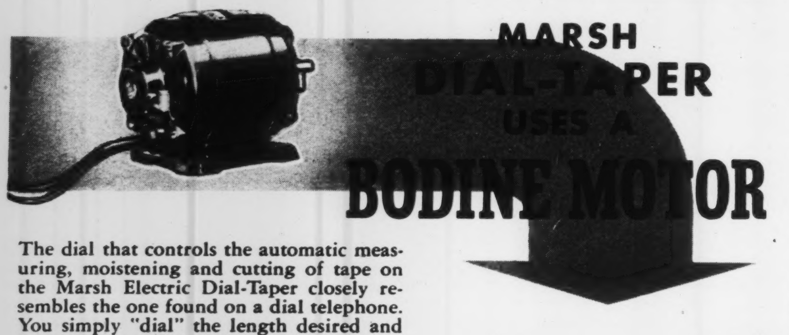
Write today for Bulletin B-30.

HOW IT OPERATES

Compressed air is dried as it crosses coils . . . condensate drops into automatic trap below. Dried air is then cleaned through seven layers of canton flannel, and passed through shaft to the instrument air lines.

CLEAN DRY AIR

HANKISON Corporation
291 Renton Bldg., 1501 Beaver Ave.
Pittsburgh 33, Pa.

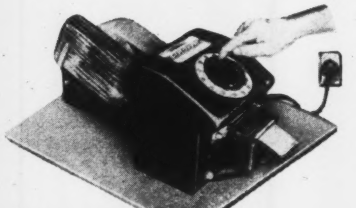


MARSH DIAL-TAPER USES A BODINE MOTOR

The dial that controls the automatic measuring, moistening and cutting of tape on the Marsh Electric Dial-Taper closely resembles the one found on a dial telephone. You simply "dial" the length desired and in a split second the piece of tape is accurately measured, cut-off and moistened with warm water. Motive power is supplied by a Bodine fractional horsepower motor.

"Bodine Motors proved their quality and dependability in our electric stencil machine," reports the Marsh Stencil Machine Co. "Our Dial-Taper required a motor that would give continuous service with minimum attention, fit into a limited space, be totally enclosed to prevent failure in relatively dusty locations, and capable of cyclic operation up to 5,000 times per 8 hour work day. One of your standard motors met all our requirements and our field experience indicates that we made a wise selection."

If you have a motor application problem, it will pay you to consult Bodine engineers.



OUR REPRESENTATIVES THOMAS REGISTER

BODINE Fractional Hp Electric MOTORS

Bodine Electric Co., 2244 W. Ohio St., Chicago 12, Ill.

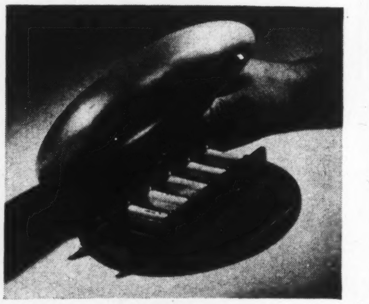
THE POWER BEHIND THE LEADING PRODUCTS

are also available with a variety of enclosures and terminal connections. New "Type 44" rotary stepping switch (Fig. 2) has a maximum self-interrupted speed of approximately 80 steps per second; is available with 10 positions (plus "home") in one, two or three levels, or with 20 or 30 positions (plus "home") in one level; switch is designed for any d-c. operating voltage up to 110.—*Automatic Electric Co.*, 1033 *W. Van Buren St., Chicago 7, Ill.*

Mention No. 559 when filling out card.

Corona-protected High-voltage Resistor

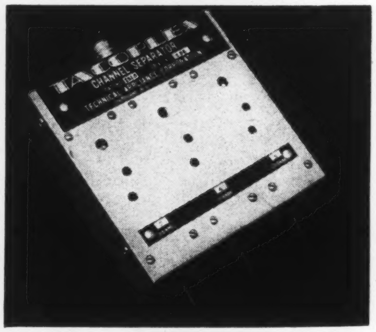
New "Type 1001" high-voltage resistor provides voltage drops from 5 to 100 kv., involving a maximum current drain of 1 ma, for voltage measurings operations. Housed in a spun-aluminum corona shield, unit contains five series-connected 1-megohm resistors rated at a precision of 0.1 percent at 74 F. Each of these units, 2.75 in. high by 10 in. in diameter, bears a normal rating of 5 kv., a maximum rating of 7.5 kv.—*Astro Electric Co.*, 1300 *Old Country Rd, Belmont, Calif.*



Mention No. 560 when filling out card.

Channel Separator

New channel separator for use with "Tacoplex Master Antenna Distribution System" in community TV installations, is available as a two-channel model "No. 1512," or a three-channel model "No. 1513." Both feature a high transfer of energy with extremely low loss.—*Technical Appliance Corp., Sherburne, N. Y.*



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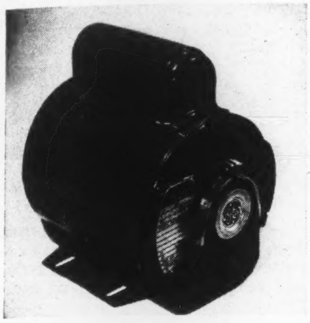
FHP Motors

New "Form G" line of fractional-horsepower motors are said to embody "many radically different and advanced design features." They weigh as much



as 51 percent less per horsepower than models replaced. Versatility of application has been broadened and appearance modernized.—*General Electric Co., Schenectady 5, N. Y.*

Mention No. 562 when filling out card.

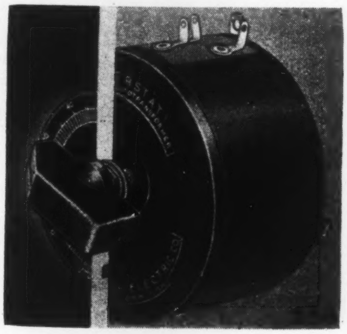
Control Relay

New electronic control relay is designed to operate in conjunction with a differential-transformer transmitter (for pressure, flow, motion, force, etc.) which has been adjusted so that its zero position is at control point. This position is sensitive to less than 0.0001 inch: as transmitter armature is displaced by a change in controlled variable, a signal is generated and control relay either pulls in or drops out, depending on direction of signal.—*Automatic Temperature Control Co., 5200 Pulaski Ave., Phila. 44, Pa.*

Mention No. 563 when filling out card.

Variable Transformer

New "Powerstat Type 10" is rated 120 volts, 60 cycles, single-phase input with an output of 0-120/132 volts, 1.25 amperes, 150/165 va.; is designed for



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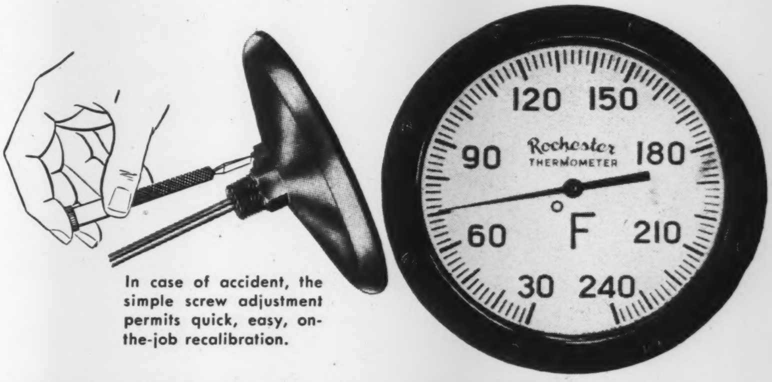

In case of accident, the simple screw adjustment permits quick, easy, on-the-job recalibration.

DON'T DROP IT! BUT IF YOU DO...

ROCHESTER DIAL THERMOMETERS are built to take severe blows without damage to their sensitive movements. But when hit hard enough to knock them out of adjustment, all you need is a screwdriver to put them right back on the job—as accurate as ever. This unique Rochester recalibration feature eliminates the danger of costly production errors due to inaccurate readings.

WELDED STAINLESS STEEL construction makes Rochester thermometers more durable, sensitive, pressure tight and resistant to corrosion than any before offered. Backed by 35 years of instrument making experience.

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50, 100, and 150 watt applications. It is said to be "the smallest physically and electrically of any variable transformer manufactured." It will supply a continuously-adjustable voltage to any load up to its rated capacity. It is designed for single-hole mounting and has a projection on base for keying to panel.—*The Superior Electric Co., Bristol, Conn.*

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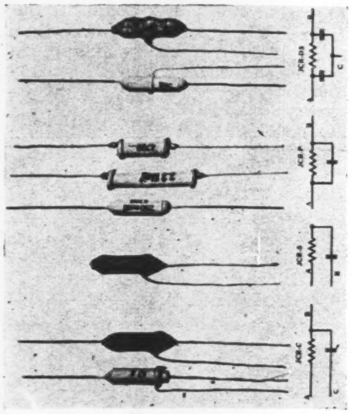
Capacitor-resistors

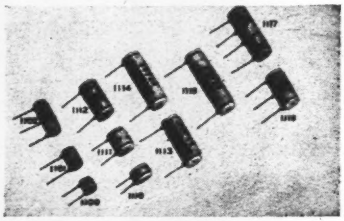
New "Capristors" (combinations of capacitors and resistors) are said to reduce assembly time, save space, reduce costs and provide full ratings of equivalent standard resistors and capacitors. They are equivalent to simple forms of printed circuits: larger but providing higher ratings.—*Jeffers Electronics, Inc., DuBois, Penna.*



Mention No. 565 when filling out card.

Subminiature Resistors

New series of subminiature resistors are available in resistance values from 20,000 ohms to 2 megohms, and in sizes from 0.25-in. dia. x 1.375-in. length

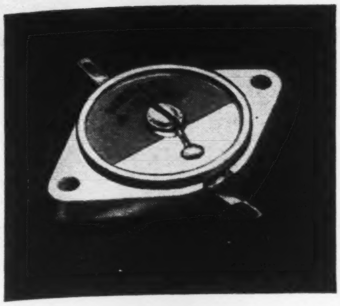


Maximum values of resistance may be obtained by use of various types and sizes of wire.—*Daven Co., 191 Central Ave., Newark, N. J.*

Mention No. 566 when filling out card.

Trimmer Capacitors

New "Type AO8" ceramic trimmer capacitors for use in circuit applications where maximum stability of capacitor characteristics is of utmost im-



portance are announced. — *Sprague Electric Co., North Adams, Mass.*

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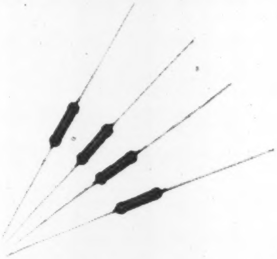
Stable Resistors

New "Type DDC" Deposited Carbon and "Type BOC" Boron Carbon resistors provide higher resistance values in less space and at lower cost than wire-

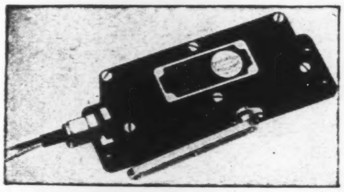


wound precisions. Boron Carbon resistor provides high degree of temperature stability. Both units are rated at ½ watt; body length is 9/16 in.; diameter of outside caps is 5/32 in.—*International Resistance Co., 401 N. Broad St., Phila. 8, Penna.*

Mention No. 568 when filling out card.

Counter-actuating Switch

New heavy-duty switch, developed to withstand hundreds of millions of operations in electric-counter actuation, may be operated by reciprocal motion

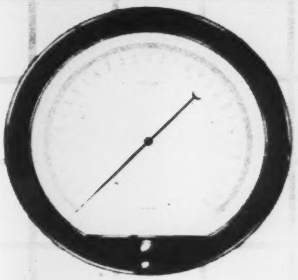


or by complete revolution of shaft. In rotary operation, switch is closed 140 deg. and open 220 deg. Arm position is adjustable. Minimum operating torque, 2 inch-ounces. Rated 10 amps at 115 v. or 5 amps at 230 v. a.c. Length, 6 inches.—*Production Instrument Co., 702 W. Jackson Blvd., Chicago 6, Ill.*

Mention No. 569 when filling out card.

Miniature Lever Switch

New miniature telephone-type lever switch has single-hole mounting. Standard contact arrangements available for various switching requirements. Con-



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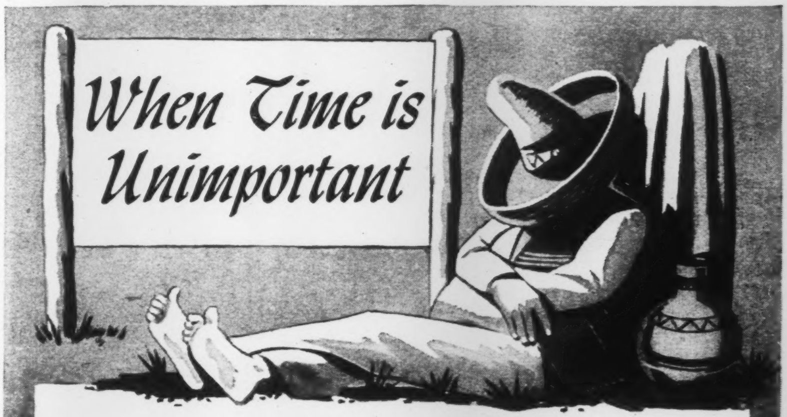

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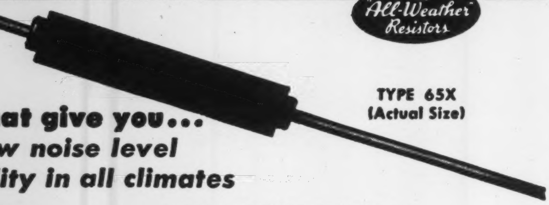
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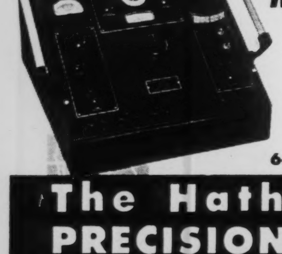
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tacts are pure silver (silver-palladium also available), rated at 1 ampere, 110 v. a.c., non-inductive load. Each switch is tested to withstand 1500 v. a.c. between contacts and frame.—*General Control Co.*, 1200 *Soldiers Field Rd., Boston* 34, *Mass.*

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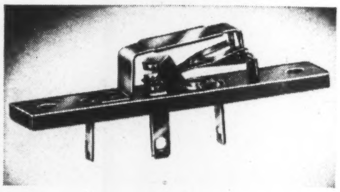
Open-blade Snap-acting Switch

New "Type E" switch requires space only 1.25 by 0.19 by 0.38 in. exclusive of terminals and terminal strip; will handle resistive loads of 10 amps at 125 v. a.c. and 5 amps at 250 v. a.c. Positive wiping action makes switch adaptable to use with tungsten-filament lamp loads. S-p. d-t. contacts for n-o. or n-c. circuit control.—*Unimax Switch Div., The W. L. Maxson Corp.*, 460 *W.* 34*th St., New York* 1, *N. Y.*



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Fractional-hp. Motor

New "Model 1120" universal motor, rated 0.025 to 0.08 hp., is one of "EMC" motors developed for mixers, laboratory equipment, etc., where gear units are not used. Housing is ventilated. Porous bronze sleeve bearings have felt oil reservoir. Internal fan is standard. Weight is 2 lbs. No-load speed is 15,000 rpm.; full-load speed is 7500 rpm.—*Howard Industries, Inc., Racine, Wis.*

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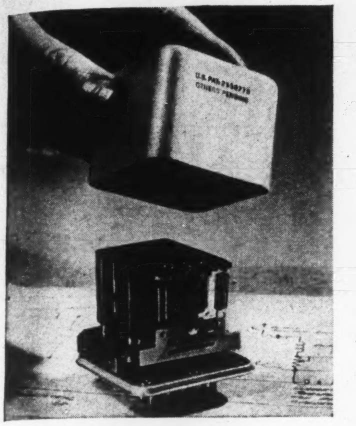
Control Relay

New "Regohm Size 3" is a plug-in unit for converting low-power-level signals into signals of higher level. Can be utilized in voltage, current, or

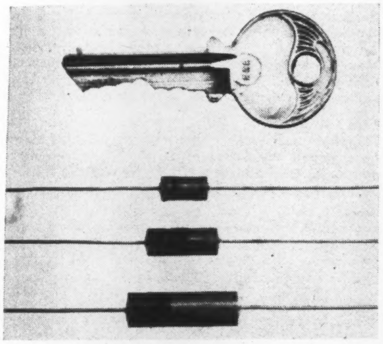


speed regulation, and servo systems; can be built with 20 standard fingers of 1-amp. 12-watt capacity, or 10 extra-heavy fingers of 3-amp. capacity. Minimum of 1.5 watts is required for coil current.—*Electric Regulator Corp., South Norwalk, Conn.*

Mention No. 573 when filling out card.

R-f. Choke Coils

New series of small r-f. choke coils in wide range of inductance values are made with insulated copper wire and have a molded jacket made of mineral-filled thermosetting compound for use under severe service conditions. Coils have no shorted end turns and windings are soldered to leads.—*Jeffers Electronics, Inc., Dubois, Penna.*



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Twin Power Triode

New "Type 6082" is a low-mu, high-perveance, twin power triode designed for use as regulator tube in stabilized d-c. power-supply units. Each unit has a mu of 2, a transconductance of 7000 micromhos, and a plate-dissipation rating of 13 watts.—*Tube Dep't, Radio Corp. of America, Harrison, N. J.*

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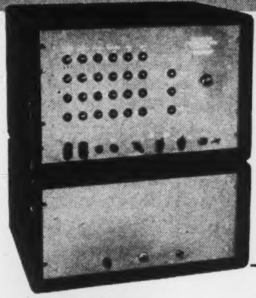
Deflection Yoke

New "Type 212D1" deflecting yoke, designed especially for use with "5ZP-16" flying-spot cathode-ray tube, has core structure designed to minimize



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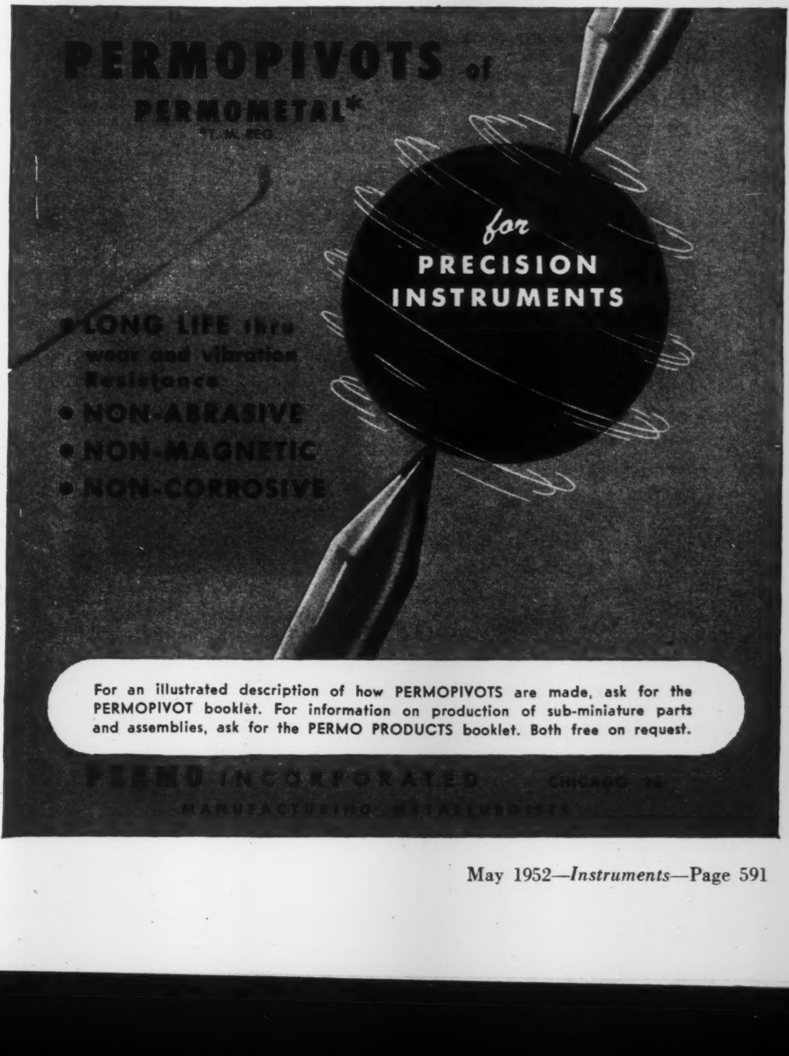

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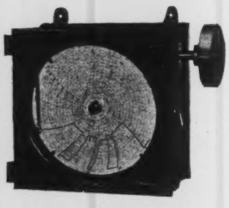

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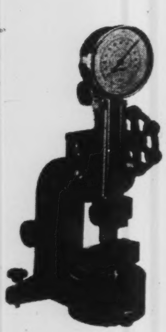

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leakage flux and thus to minimize deformation of flying spot.—*Tube Dep't, Radio Corp. of America, Harrison, N. J.*

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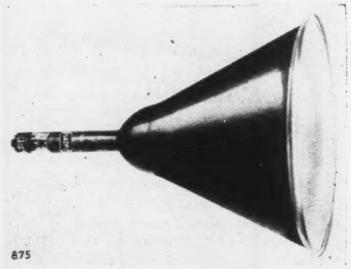
Oscillograph Tube

New "16ADP7" is 16-inch metal-shell oscillograph tube designed for radar-indicator and oscillographic applications. Magnetic focus and magnetic deflection are used. P7 phosphor has long persistence. Flat surface facilitates use of calibrated scale.—*Tube Dept., Radio Corp. of America, Harrison, N. J.*



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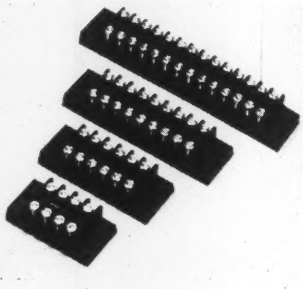
Terminal Boards

New electric terminal boards are molded of mineral filled molding compound, spec. number MIL-P-14A. Boards have from 8 to 28 terminals.—*Auburn Button Works, Inc., Auburn, N. Y.*



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INSTRUMENT EVENTS CALENDAR

May 18-25
Achema X—Chemical Meeting and Exhibit, Frankfurt, Germany. At the same time and place the 25th International Congress for Industrial Chemistry will be held. Instruments will be exhibited. For information write Dr. H. Bretschneider, Deutsche Gesellschaft fuer Chemisches Apparatewisen, Frankfurt am Main 13, P.O. Box 1337, Germany.

May 20-23
National Conference on Weights and Measures, Wardman Park Hotel, Washington, D.C. For information write Mr. W. S. Bussey, National Bureau of Standards, Washington 25, D.C.

May 22-23
"Electronics and Machines" Symposium, Professional Group on Industrial Electronics, Institute of Radio Engineers, Palmer House, Chicago. For information write Eugene Mittelmann, 549 W. Washington Blvd., Chicago 6, Ill.

May 22-24
American Society for Quality Control, Onondaga Memorial, Syracuse, N. Y. For information write W. R. Weaver, Gen. Chm., 1527 Republic Bldg., Cleveland 1, Ohio.

May 29-June 5
49th Exposition of Instruments and Scientific Material, University of Paris, Paris France.

June 2-4
Symposium on Instrumentation for the Process Industries, School of Engineering, Chemical Engineering Dept., A & M College of Texas, College Station, Texas. For information write Dr. G. L. Farrar, Director.

June 11-13
American Congress on Surveying and Mapping.
Twelfth Annual Meeting and Exhibit.
Shoreham Hotel, Washington, D. C.
For information write Walter S. Dix, Ex. Sec., P. O. Box 470, Benjamin Franklin Station, Washington 4, D. C.

June 19-21
ASME Applied Mechanics Division Symposium on Shock and Vibration Instrumentation, Pennsylvania State College, State College, Pa. For information write W. D. Kroll, Physicist, National Bureau of Standards, Washington 25, D.C.

June 23-27
ASTM 50th Anniversary Meeting and 10th Exhibit of Testing Apparatus and Laboratory Supplies, Hotel Statler, New York, N. Y. For information write Robert J. Painter, Asst. Sec., American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

July 28-Aug. 1
Gordon Research Conference on Instrumentation sponsored by the American Association for the Advancement of Science, Colby Junior College, New London, N. H. For information write W. George Parks, Director, Dep't of Chemistry, University of Rhode Island, Kingston, R. I.

Sept. 4-13
International Society of Photogrammetry, Shoreham Hotel, Washington, D. C. For information write L. Ray Smart, U. S. Geological Survey, Trimetrogon Section, Washington 25, D. C.

Sept. 8-12
Instrument Society of America.
Seventh National Instrument Conference and Exhibit.
Public Auditorium, Cleveland, Ohio.

Sept. 22-30
Third Instruments and Measurements Conference and Exhibition, Stockholm, Sweden. For information write Mr. Yngve Axner, Kungl. Tekniska Hogspolan, Stockholm 70.

Sept. 29-Oct. 1
Eighth National Electronics Conference and Exhibition.
Sherman Hotel, Chicago.
For information write Karl Kramer, Ex. Sec., 852 E. 83rd St., Chicago 19.

October
Scientific Apparatus Makers Association.
Midyear Meeting of Recorder-Controller Section.
Seaview Country Club, Absecon, N. J.

Nov. 5-9
Scientific Apparatus Makers Association.
Midyear Meeting of Industrial Instrument, Laboratory Apparatus, Laboratory Equipment, Optical, Aeronautical, and Military Instruments Sections.
The Homestead, Hot Springs, Virginia.

Nov. 17-18
AIEE Technical Conference on Electrically-operated Recording and Controlling Instruments. Benjamin Franklin Hotel, Philadelphia, Pa. For information write G. L. Broomell, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia 44.

Dec. 3-5
Annual Meeting, Society for Experimental Stress Analysis, Hotel McAlpine, New York City. For information write W. M. Murray, Sec.-Treas., P.O. Box 168, Cambridge 39, Mass.

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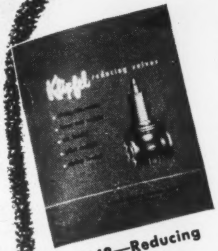
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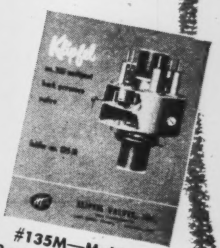
#135M—Multiport Back Pressure Valves

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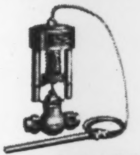
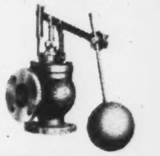
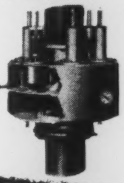

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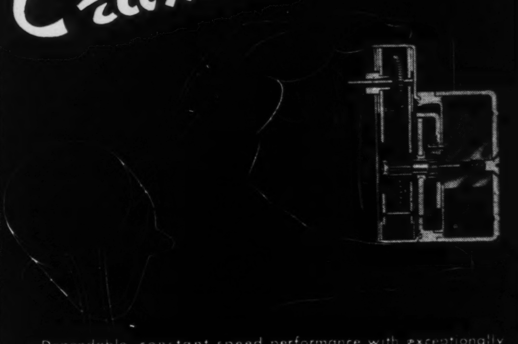

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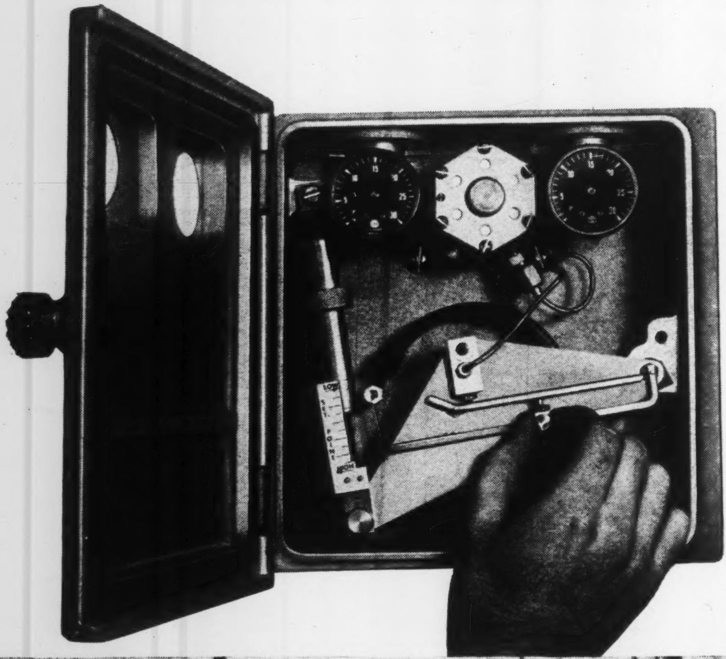
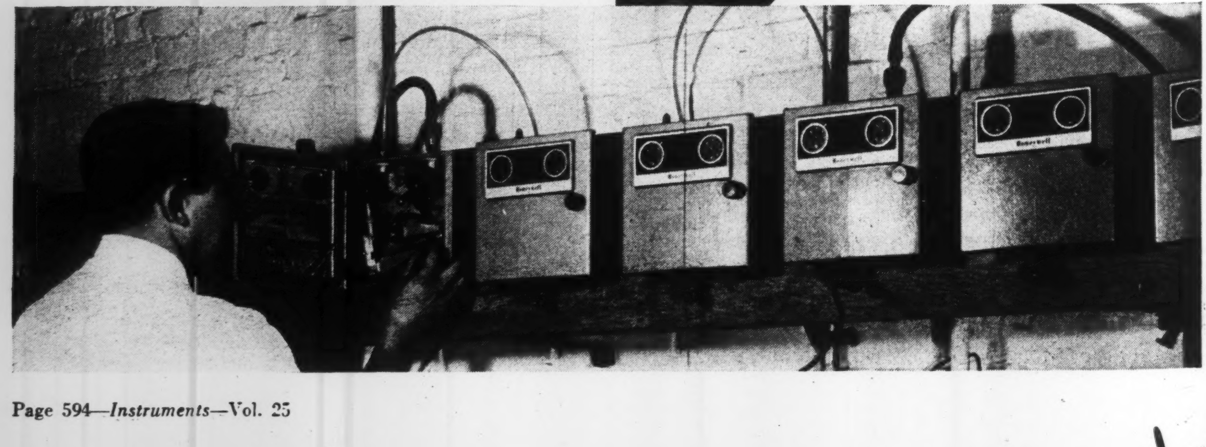


A look inside the Honeywell Pressure Pilot shows its simple design, rugged construction, and accessibility of all adjustments.



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VALVE

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VALVE CONTROL of LIQUID FLOW

By
RUSSELL MILHAM and ALLAN R. CATHERON
The Foxboro Company

Selection of a valve type and size for a flow-control problem involves analysis of valve characteristics. The drop ratio in a system changes the characteristics of a valve and affects control quality. These significant factors are presented in practical form.

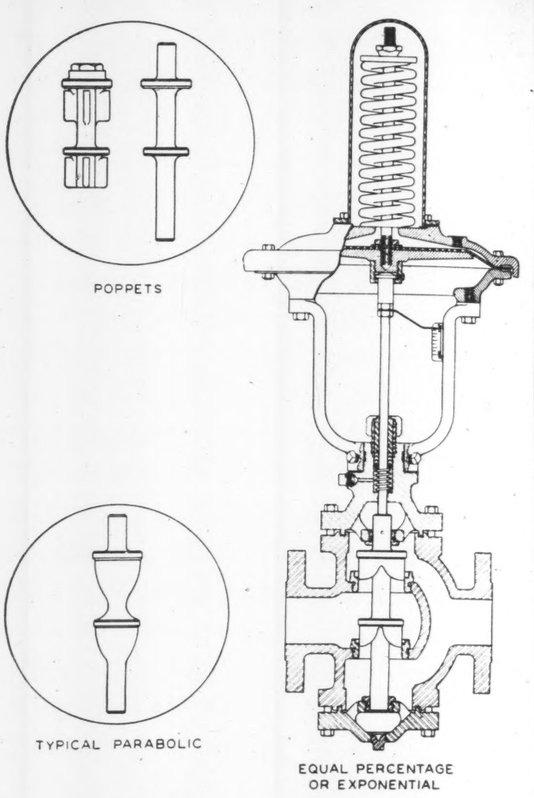

Fig. 1. Types of commonly used valves.

THIS article appraises the flow-lift characteristics of various control valves under different system pressure conditions, and relates these characteristics to quality of control. Any study of valve reaction cannot be isolated completely from the controller reaction because each is an integral part of the controlled-system loop. Let us review briefly the accepted theories of valve characteristics and the practical limitations of published data.

INNER VALVES

Three inner-valve types (Fig. 1) have become generally established in industry as the most satisfactory for use in automatic control loops. These, which were selected for study and test, are (1) the equal percentage, or exponential, (2) the parabolic, and (3) the poppet. The poppet is shown in two commercially available forms—the so-called wing-guided and the top-and-bottom guided. The tests were conducted with the wing-guided design.

TEST EQUIPMENT

One-inch, inch-and-a-half, and two-inch sizes of each type valve were studied. The maximum size was limited by the capacity of the test system. The equipment used for the tests consists of a water flow line of 2-in. schedule 40 pipe (with flanged joints and 6-foot-radius bends). It serves as either a 20-foot or a 140-foot straight run with primary element and valve located at any of several points. Flow rates up to 100 gallons per minute can be delivered by the centrifugal pump. Fig. 2 shows the system in detail. For this series of valve studies the short line was used with the control valve located just above the discharge into the sump, and the primary flow-measuring element (an orifice) about 3 feet upstream.

The basic data were obtained using a controlled head-pressure to induce flow in the line. This permitted the plotting of steady-state valve characteristic curves for constant drop-ratios regardless of valve position. *Drop ratio* is the term used to express the distribution of the total pressure-drop in the system between the valve and the remainder of the system. It is the ratio of the total drop across the system (excluding valve drop) to the pressure drop across the valve—that is,

$$(\Delta p_s - \Delta p_v)\,\Delta p_v,$$

where Δp_s is the drop across the entire system from pump to sump (including valve drop) and Δp_v is the drop across the valve.

In a theoretical friction-free system, the only drop occurs across the valve, and the drop ratio remains a constant 0:1 regardless of valve position. However, in most practical applications the drop ratio changes with valve position. Static (steady-state) curves were plotted from data taken with systems with constant drop ratio and also with systems having direct pumping with a centrifugal pump, where the drop ratios change radically with valve position. The former illustrate theoretical design concepts; the latter apply to common operating conditions met in field service.

All characteristic curves, except the design (0:1) ratio, were determined with the specified ratio existing only at the maximum flow. As the valves were closed, the flow decreased, and more and more pressure drop developed across the valves. Only in systems in which the drop ratio was 0:1 was the drop across the valve maintained constant throughout the stroke of the valve. The others had the specified drop ratio only at the full-open position.

VALVE CHARACTERISTICS

The static (steady-state) *design characteristics* of the three inner-valve types are presented in Fig. 3. The curves are typical of published data.

The *equal-percentage*, or exponential, plunger produces an equal percentage change in existing or instant flow (not maximum) with equal increments of change in lift. The curve is a straight line on semi-log coordinates, and a de-

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Presented at the Symposium, "The Use and Application of Control Valves," of the New Jersey Section, Instrument Society of America, Newark, N. J., April 1, 1952.

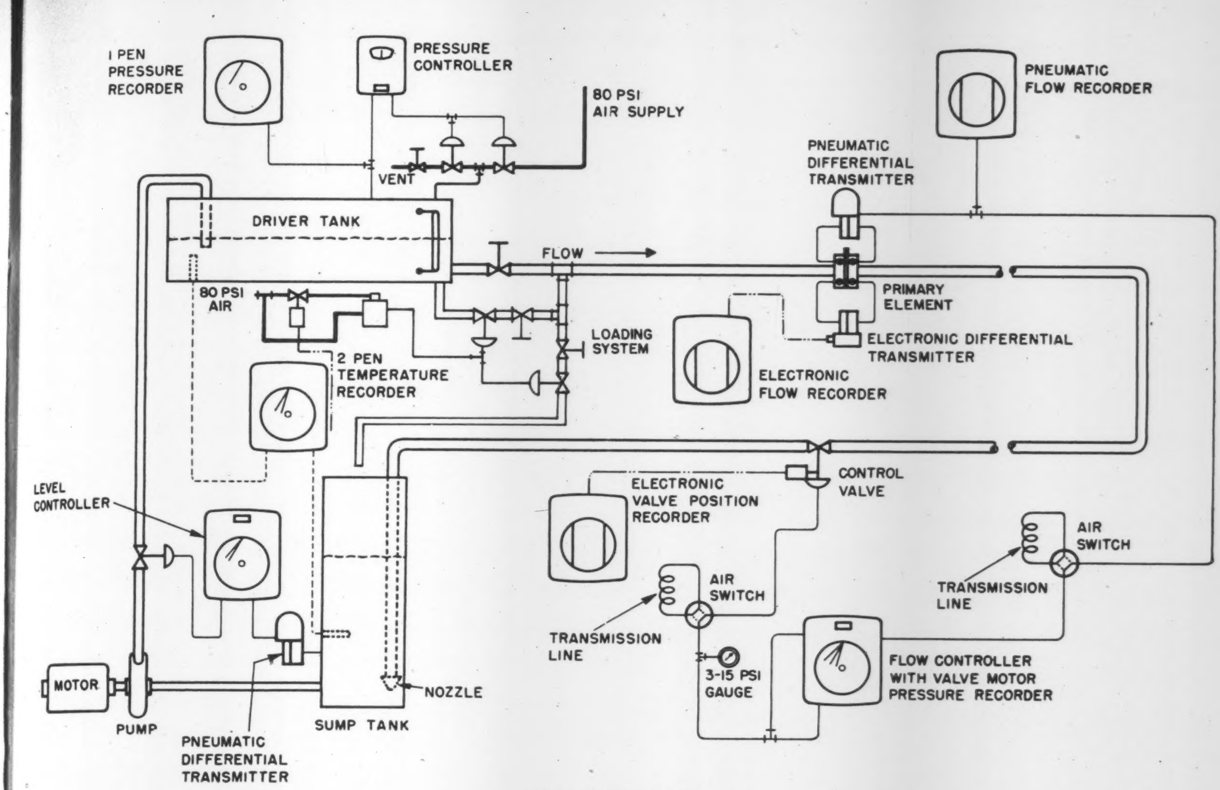
I PEN PRESSURE RECORDER
PRESSURE CONTROLLER
80 PSI AIR SUPPLY
PNEUMATIC FLOW RECORDER
PNEUMATIC DIFFERENTIAL TRANSMITTER
VENT
DRIVER TANK
FLOW
PRIMARY ELEMENT
80 PSI AIR
LOADING SYSTEM
ELECTRONIC DIFFERENTIAL TRANSMITTER
2 PEN TEMPERATURE RECORDER
ELECTRONIC FLOW RECORDER
CONTROL VALVE
ELECTRONIC VALVE POSITION RECORDER
LEVEL CONTROLLER
AIR SWITCH
AIR SWITCH
TRANSMISSION LINE
TRANSMISSION LINE
3-15 PSI GAUGE
FLOW CONTROLLER WITH VALVE MOTOR PRESSURE RECORDER
MOTOR
NOZZLE
PUMP
SUMP TANK
PNEUMATIC DIFFERENTIAL TRANSMITTER

Fig. 2. Test system.

sign rangeability of 50:1 is indicated. The majority of proportional-control valves are of this type. The reasons for its wide acceptance include compensation for pressure changes in the line upstream or downstream of the valve, and uniform sensitivity of the process to controller action across the scale.

The *poppet* (which is linear only in respect to area versus lift) shows that the major portion (70-80 percent) of the flow is attained at approximately 50 to 60 percent of lift. Inherent in the mechanical design of this type of valve is comparatively limited lift (one-eighth of nominal valve size for the double-seated design), which is all that is essential to accomplish design flow capacity from the control point of view.

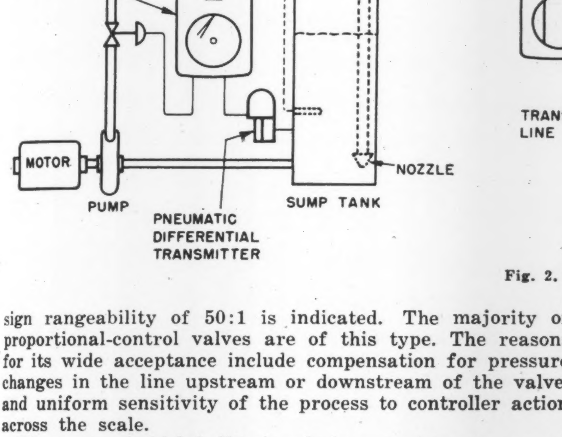

Fig. 3. Design characteristics of the basic valve types when drop ratio is 0:1.

The *parabolic* characteristic curves fall between those of the other two types and vary with the valve size. They produce an approximately linear flow-lift relationship from about 30 to 70 percent lift.

By definition these valve characteristic curves are based on (1) total system pressure drop across the control valve (drop ratio of 0:1) and (2) a constant pressure drop throughout the valve lift. It is patently evident that these two limitations do not occur generally in process installations and, therefore, must be considered only as the *design characteristics* of the control valves.

EFFECT OF PRESSURE-DROP DISTRIBUTION

Relatively modest amounts of test data have been published to substantiate the theoretical, mathematical analyses of valve characteristics under varying system pressure drops. This data could help to answer the practical and perennial question of the optimum pressure drop for good flow control. As a parallel study to other flow-control work (references 1, 2, and 3) the following analysis is limited to liquid-flow control. Specific mathematical correlations will be held to a minimum in this presentation but may be readily derived from the curves herein.

Flow control cannot be obtained without pressure drop, and the higher the percentage of the available system pressure drop assigned to the valve, the less the degree of control difficulty or the greater the quality of performance.

The conditions under which these data were obtained are constant input and output pressures in a flow system consisting of source, line, primary element, valve, and sink. Therefore, there is a fixed over-all pressure drop across the system, which may be distributed in an infinite number of ways depending on the resistances of the system components. To take the extreme case, it is obvious that if the pressure drop is distributed elsewhere in the system than across the valve, the valve opening can have no effect on the flow, and control is lost completely. If only a small part of the drop is allotted to the valve, the latter must move a large part of its stroke to have an appreciable effect on the flow. Conversely, if the ideal state of placing all of

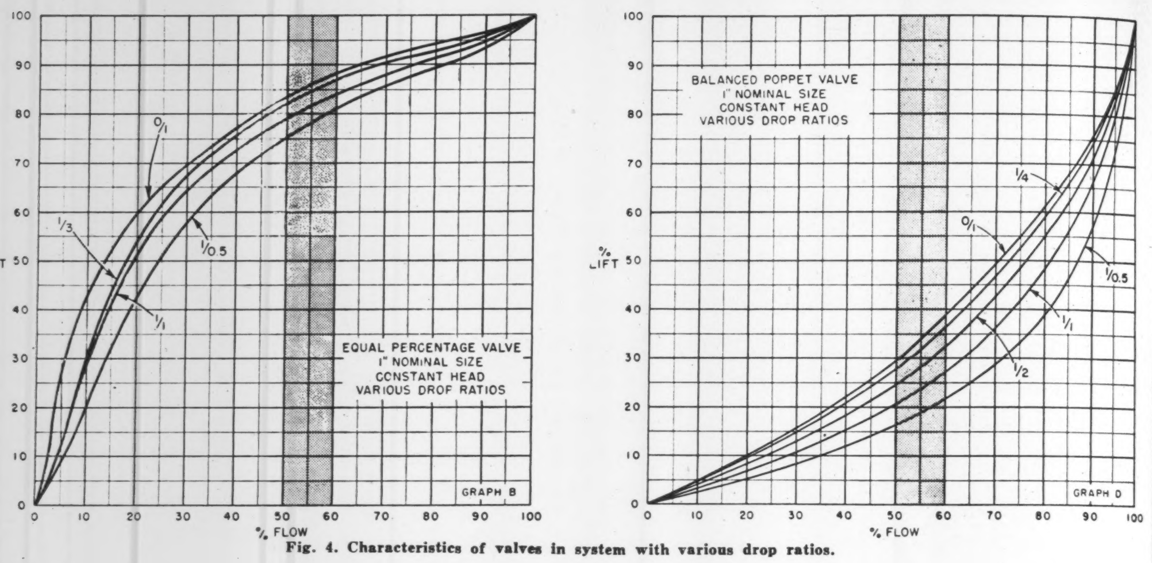

Fig. 4. Characteristics of valves in system with various drop ratios.

the drop across the valve could be realized, the valve would then have the greatest possible effect on the flow, with a minimum of lift necessary for a given flow change.

The conventional way of plotting valve characteristic curves is on semi-logarithmic coordinates, so that the action of an equal-percentage valve appears as a straight line. This form is not used here because rectilinear coordinates illustrate several important points.

Fig. 4 shows the steady-state effect of different system pressure-drops (drop ratios) on the valve characteristic. The curves show how the characteristic curves deviate from the design characteristic with changes in drop ratio from 0:1 to 1:0.5. This is equivalent to assigning from 100 to 33 percent of the available system drop to the valve under maximum flow conditions, and is analogous to approximately a two-to-one load change across the entire system. The curves are shown for equal-percentage and balanced-poppet valves. The parabolic-valve curves fall in between the two sets shown, as in Fig. 3.

The dark areas in Fig. 4 illustrate the 10-percent change in flow from 50 to 60 percent of flow. Observe that essentially constant lift changes acomplished the flow change with each of the valve types, despite the change in drop ratio. The slopes of the curves are relatively flat in this reasonable (from the percentage-of-flow point of view) operating region. Note that the poppet characteristic is well into its sensitive range.

The curves imply that the equal-percentage valve has greatest usability (due to constancy of sensitivity) in the upper third of lift; the parabolic valve from about 30 to 70 percent of lift; the poppet up to about 40 percent of lift. This might lead to the assumption that the three valve types could be applied selectively, with good control results, by careful sizing to utilize the most effective portion of the valve lift. However, this approach is generally impractical and further analysis first must be made before drawing such a conclusion.

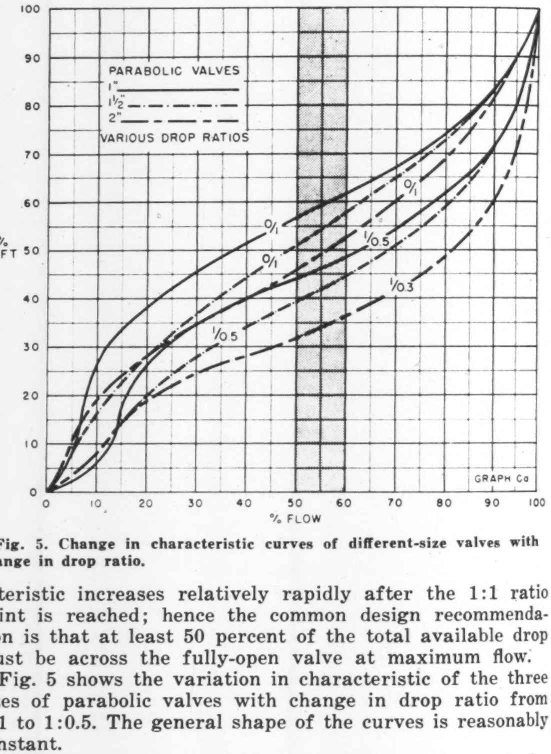

Fig. 5. Change in characteristic curves of different-size valves with change in drop ratio.

Note that the departure from the design, or ideal, characteristic increases relatively rapidly after the 1:1 ratio point is reached; hence the common design recommendation is that at least 50 percent of the total available drop must be across the fully-open valve at maximum flow.

Fig. 5 shows the variation in characteristic of the three sizes of parabolic valves with change in drop ratio from 0:1 to 1:0.5. The general shape of the curves is reasonably constant.

An interesting comparison (see table) can be made by

Continued on page 634

	Equal-percentage Valve		*Parabolic Valve*		*Balanced-poppet Valve*	
% Lift	0:1 *Drop Ratio*	1:0.5 *Drop Ratio*	0:1 *Drop Ratio*	1:0.5 *Drop Ratio*	0:1 *Drop Ratio*	1:0.5 *Drop Ratio*
10	0.33	0.72	0.96	2.0	2.98	4.97
20	0.49	1.20	1.36	2.56	5.4	7.81
30	0.73	1.68	1.96	4.08	7.1	9.94
40	1.01	2.28	3.68	6.56	8.66	11.36
50	1.62	3.0	6.9	8.48	9.94	12.35
60	2.40	3.84	9.0	12.5	11.36	12.92
70	3.60	5.28	12.0	14.24	12.35	13.35
80	5.40	7.08	14.0	15.2	13.35	13.77
90	8.04	9.96	15.0	15.7	13.92	14.06
100	12.00	12.0	16.0	16.0	14.2	14.2

CAPACITOR-CHARGING CIRCUITS

Charging large capacitors from gas-tube-regulated supplies without excess surges is an interesting problem.

By RONALD L. IVES
Cornell Aeronautical Laboratory

CHARGING of large capacitors imposes a considerable strain on the average regulated power supply, particularly when the switching device is a thyratron. In some instances the drawdown due to the sudden switching in of the load not only causes extinction of the regulator tubes, but also causes the thyratron to stop conducting before the capacitor acquires the desired charge. This difficulty has made use of capacitor-discharge recorders uneconomical at low counting rates(1,2).

USE OF VR TUBES

When a simple regulated supply cannot carry the surge loads satisfactorily, the trouble can be corrected by adding more voltage regulator tubes in parallel, and by reducing the series dropping resistor, as in Fig. 1. Increase in the capacity of the final filter capacitor may also be desirable. However, this expedient is wasteful because each VR tube in the system draws current at all times.

A more economical method is to use one or more regulator tubes as a shorting switch across all or part of the series dropping resistor, as in Fig. 2. Here, so long as the voltage drop across the VR tube is less than the ignition voltage of the tube, the VR tube is nonconducting and circuit resistance is that of the dropping resistor. The shunt resistance of a nonconducting VR tube is usually several megohms and has no effect on the circuit.

When a heavy drain is placed on the circuit, the voltage drop across the resistor increases. If it exceeds the ignition voltage of the VR tube, the tube conducts, and its resistance drops to about 5,000 ohms for a VR-150 (or 3500 ohms for a VR-105). This resistance is shunted across the dropping resistor. Any number of VR tubes in parallel can be used. A small resistor in series with each tube is desirable so that one tube does not carry an undue portion of the current.

This system, although having about the same initial cost as that in Fig. 1, is more economical of power, has much longer tube life, and does not introduce heat-disposal problems. Its chief disadvantage is that it imposes heavy surge loads on the power supply when the capacitor is switched into charging position.

RESERVOIR SYSTEM

An improvement embodying an electrical reservoir is shown in Fig. 3. Here, the surge current for charging the capacitor is not drawn directly from the filter system, but is drawn initially from a storage capacitor. This capacitor recharges at a relatively slow rate from the main filter system so that there is no severe surge load on the rectifier and filter.

When the power is first turned on, V2 lights and stabilizes the voltage at the plate of V1 at 150 volts. Tube V3 also lights, due to the charging current of C2, but soon goes out because the voltage on C2 reaches approximately 255 volts. Initial drain on the power supply is 60 ma. This rapidly declines to approximately 30 ma. and remains there until thyratron V1 fires. When this takes place, the charging current of C1 reduces the voltage across V2, which goes out. Immediately, the voltage across V4 and V5 increases, and soon reaches the ignition value for these tubes. When V4 and V5 fire, the charge from C2 is delivered to C1. This reduces the charge on C2, so that its terminal voltage falls, permitting V3 to conduct.

Because C2 is large compared to C1, the drop in its terminal voltage due to charging C1 is small, and the voltage on the thyratron plate cannot fall to the extinction value.

As the charge on C1 increases, its charging rate falls, so that the voltage drop across R1 decreases, permitting V2 to conduct again before C1 is fully charged. This limits the plate voltage on V1 to 150, accordingly limiting the voltage attained by C1.

Shortly before V2 conducts, voltage

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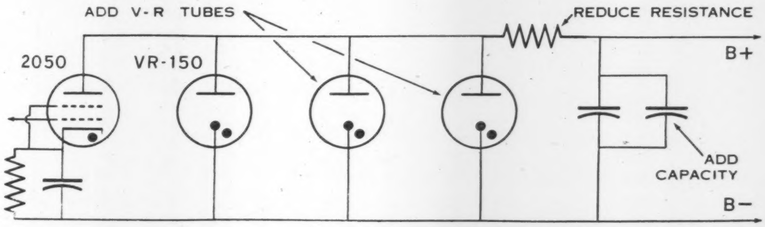

Fig. 1. Charging a capacitor in the cathode circuit of a thryatron by adding VR tubes, adding capacity, and reducing the dropping resistor in the regulated supply.

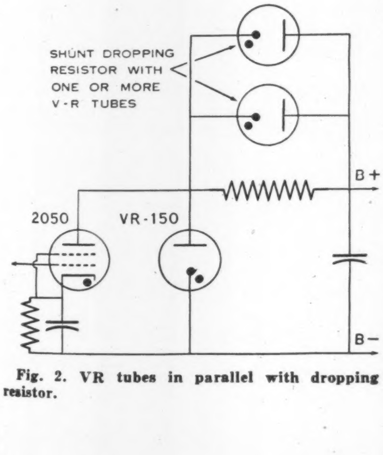

Fig. 2. VR tubes in parallel with dropping resistor.

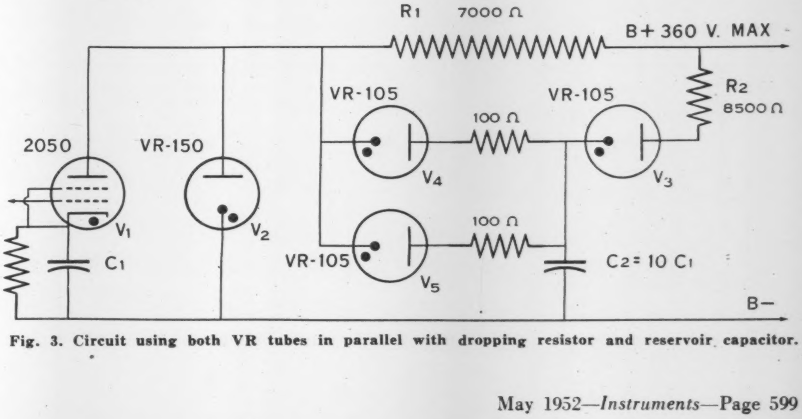

Fig. 3. Circuit using both VR tubes in parallel with dropping resistor and reservoir capacitor.

MOISTURE MEASUREMENT

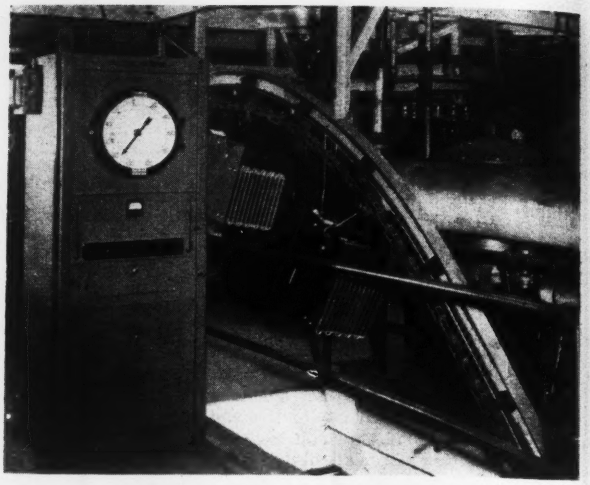

Fig. 1. General Electric dew-point apparatus.

By R. E. HADADY

American Instrument Company, Inc.

The factors of greatest importance in moisture measurement are dew-point range, accuracy, temperature range, speed of response, simplicity of operation, and relative price. Here are comparisons of various instrumental methods.

MOISTURE in an atmosphere can be measured by several methods. The general classifications of moisture-measuring instruments are listed in the table. A specific type of instrument is noted for each classification.

This article describes and compares the commonly used methods for moisture measurement with regard to dew-point range, accuracy, temperature range, speed of response, complexity of operation, and price. This information will assist the instrumentation engineer to select the particular type of instrument best adapted to a given application.

Selection of the method for measuring moisture is governed by such factors as accuracy required, cost, space limitations, and whether or not a continuous record is required.

TERMINOLOGY

In any discussion involving the measurement of moisture, a clear understanding of the terminology to be used is of primary importance. The following terms are used in this article:

Dry-bulb temperature—air temperature as indicated by any type of thermometer not affected by water vapor.

Wet-bulb temperature—the temperature as determined by a thermometer with its bulb encased in a fine-mesh fabric bag moistened with distilled water and subject to air having a minimum velocity of 15 feet per second.

Dew-point temperature—the temperature at which condensation of water vapor takes place in a given space.

Absolute humidity—weight of water vapor per unit volume of space occupied (usually expressed in pounds of water vapor per pound of dry gas).

Relative humidity—ratio of the partial pressure of the water vapor present to the saturation pressure of water vapor at the existing temperature.

Percent saturation—ratio of the absolute humidity to the absolute humidity required for saturation in a given space.

Percent relative humidity and percent saturation are occasionally confused, probably because they have nearly the same value for any given condition.

GRAVIMETRIC

Measuring moisture gravimetrically consists of exposing a known weight of hygroscopic material, such as phosphorus pentoxide, to the atmosphere whose moisture content is to be measured. Sufficient time and proper conditions are provided to bring all the atmosphere into contact with the desiccant so that complete absorption of water vapor can take place. The desiccant is then reweighed. The difference in weight is the amount of water vapor present in the atmosphere. The gravimetric system is a basic system and, if proper technique and a precise balance are used, a high accuracy is possible. This provides a standardizing system for secondary methods of moisture measurement.

DEW POINT

Measurement of moisture by dew point also is a basic system. By definition, dew point is the temperature at which condensation of water vapor takes place in a given space. There are two common systems of measuring dew point.

The *mirror-surface method* consists of exposing a material with a mirror-like surface to the atmosphere to be tested and reducing the temperature of the material until water droplets (dew) form upon the mirror surface. The temperature of the surface when droplets just start to form is the dew-point temperature. The mirror surface is used only to determine the instant when moisture begins to condense. Automatic recording dew-point instruments are available using a mirror surface and photoelectric cell in conjunction with the necessary electrical circuits and refrigeration apparatus. Fig. 1 illustrates equipment which operates on this principle and which is manufactured by the General Electric Co.

In contrast to the mirror-surface scheme of measuring dew point, the *fog-chamber system* employs variation in pressure rather than temperature, and the occurrence of fog in a transparent sampling chamber rather than moisture condensation on a surface. Equipment of this type is manufactured by the Illinois Testing Laboratory and is illustrated in Fig. 2.

WET AND DRY BULBS

Many instruments operate on the principle of measuring wet- and dry-bulb temperatures. The temperature of a wet-bulb thermometer is a function of the cooling effect produced by evaporation of distilled water from the

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Presented at a meeting of the Washington and Baltimore Sections, Instrument Society of America.

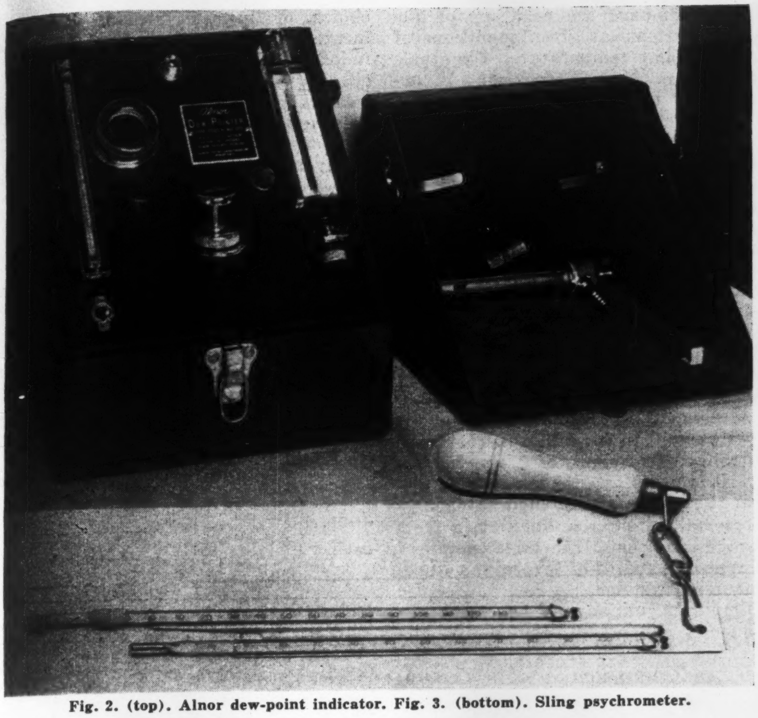


Fig. 2. (top). Alnor dew-point indicator. Fig. 3. (bottom). Sling psychrometer.

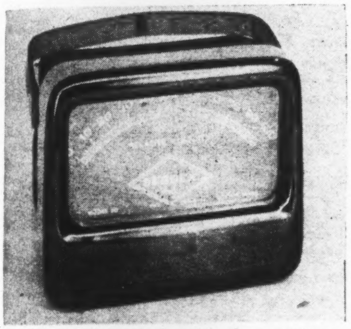


Fig. 4. Mechanical-system hygrometer.

wick enclosing the sensing bulb. The evaporation of moisture from the wick depends in turn on the vapor pressure of the moisture in the surrounding atmosphere. The difference between the wet- and dry-bulb temperatures can, therefore, be correlated in terms of moisture present.

Instruments operating on the wet-dry bulb principle differ only in the method of measuring temperature. Common methods employed are: mercury thermometers, gas-bulb thermometers, resistance thermometers, thermocouples, and bimetal thermometers. A typical *sling psychrometer* in general use is illustrated in Fig. 3.

Mechanical

A large percentage of moisture-measuring instruments employ the mechanical system, particularly when low cost is a paramount consideration. The basic operating principle of a mechanical-type moisture-measuring instrument is the expansion or contraction of the operating element as it absorbs or releases moisture. This change in the physical dimensions of the operating system is mechanically coupled to a pointer moving across a scale calibrated in terms of relative humidity. The materials used as operating elements vary widely, but the principle of operation remains the same. Some materials used include human hair, animal membrane, bone, wood, and plastics. The desk-type humidity indicator (Fig. 4) is a typical instrument employing a mechanical system.

Electrical Resistance

The electrical-resistance system of moisture measurement employs as a sensing element a material which changes its electrical resistance with changes in moisture content of the surrounding atmosphere. A basic requirement of such a material is that it release its moisture in a dry atmosphere as quickly as it absorbs moisture in a wet atmosphere.

The "Aminco-Dunmore" electric hygrometer uses lithium chloride as its sensing element. This material, when aged and stabilized, maintains a reliable calibration over long periods of time. A typical sensing element of this type is illustrated in Fig. 5.

Another instrument of the resistance type, the *water-vapor indicator*, employs phosphoric or sulphuric acid as a sensing element. These materials are extremely sensitive and suitable for measuring very dry atmospheres. However, the water-vapor indicator has the disadvantage of being stable for periods of minutes rather than months. This instrument is illustrated in Fig. 6.

The *radiosonde humidity* element is a specialized type of electric hygrometer. It is designed for a one-time application in weather sounding balloons.

Absorption

The absorption system of moisture measurement has been applied in some moisture-measurement applications. The principle used is the quantitative measurement of the absorption of infrared waves, ultrasonic vibrations, or microwaves by the atmosphere in which moisture is to be measured. Certain bands of frequencies in each of these spectrums are particularly sensitive to absorption by atmospheric water vapor.

Miscellaneous

There is also a group of instruments suitable for moisture measurement but

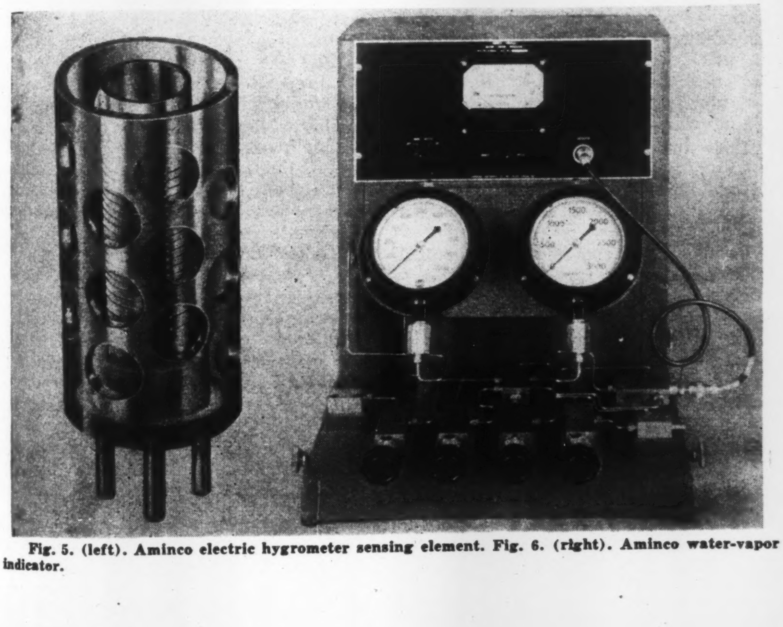


Fig. 5. (left). Aminco electric hygrometer sensing element. Fig. 6. (right). Aminco water-vapor indicator.

so specialized in their application that they have never found wide acclaim for general use.

The *thermal-conductivity system* relies on the principle that the thermal conductivity of a given gas varies as its water content.

In the *galvanic system,* a voltage is produced which is a function of the water vapor present.

The *liberation of gas* from certain chemicals as a function of the water vapor present is another specialized system of moisture measurement.

The operating ranges of the various systems for moisture measurement is the primary consideration in selecting a system suitable for a given application. The table lists the approximate range for each of the more universally used systems.

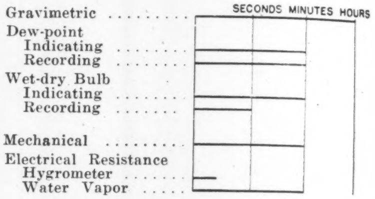
Also of major importance in selecting a moisture-measuring system for a given application is the accuracy required. It is difficult to compare the accuracy of the various systems on a single chart or graph because the relative error depends on different factors for different conditions of temperature and moisture content. However, it is easy to compare the accuracy of the various systems at given conditions of humidity and temperature. The table shows a relative comparison of accuracy for the most-used systems.

Another important factor in selecting suitable moisture-measuring equipment is the temperature range in which the system must function. The table illustrates the approximate dry-bulb-temperature operating ranges for several systems. Sampling systems frequently are employed wherein a sample of atmosphere is taken at the given temperature and heated or cooled to a temperature within the operating range of the system in use.

In many applications it is necessary that the sensing element respond rapidly to changes in the amount of water vapor present in the atmosphere. In the controlled atmosphere of a test laboratory, it is necessary for the sensing element to respond almost instantaneously to forestall intolerable fluctuation from average conditions. The table compares the response speeds of several moisture-measuring systems.

Simplicity and ease of operation are frequently important factors in the choice of moisture-measuring equipment. The table provides a general index of the systems in relation to this characteristic, and also shows the relative cost of the various moisture-measuring instruments. A graphic comparison of humidity-measuring methods is given below.

MOISTURE-MEASURING EQUIPMENT vs. SPEED OF RESPONSE



MOISTURE-MEASURING EQUIPMENT vs. DEW-POINT RANGE

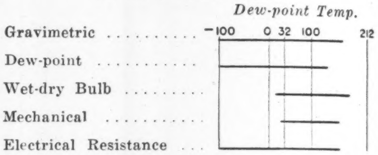


TABLE I—TYPES AND CHARACTERISTICS OF MOISTURE-MEASURING SYSTEMS

	Gravimetric	*Dew Point*	*Wet-dry bulb*	*Mechanical*	*Electrical resistance*	*Absorption*	*Miscellaneous*
Principle	Absorption by chemicals	Mirror surface. Fog chamber. "Dewcel."	Sling psychrometer. Gas-activated thermometer bulb. Electrical-resistance thermometer bulb. Bimetal thermometer.	Hair, membrane, bone, wood, moisture-sensitive plastic	Electric hygrometer. Water vapor indicator. Radiosode element	Infrared Ultrasonic Microwave	Thermal Conductivity of gas. Galvanic. Gas liberation.
Operating, or dew-point, range	—100 to 160 deg. F.	—100 to 120 deg. F.	7 to 180 deg. F.	15 to 150 deg. F.	—100 to 150 deg. F.		
Accuracy	2% of actual absolute humidity	±5 deg. F. for dew-point of minus 90 deg. F.; ±2 deg. F. for dew-points above minus 20 deg. F.	±1 deg. F. difference in wet and dry bulb.	±5% relative humidity	±1.5% relative humidity		
Error at 72°F. and 50% R.H.	0.8%	2.7%	3.6%	5%	1.2%		
Operating temperature range		—100 to 115	32 to 160	32 to 150	0 to 150		
Response speed	Hours	Several minutes	(Indicator) Several min. (Recording) Several sec.	Several min.	(Hygrometer) Less than a second (Water-vapor indicator) Several min.		
Simplicity of operation	Poor	(Indicating) Good (Recording) Excellent	Good	Excellent	(Hygrometer) Good (Water-vapor indicator) Fair		
Approx. price	$100 to $1000	(Indicating) $100 to $1000 (Recording) $1000 to $5000	(Indicating) Below $100 (Recording) $100 to $1000	Below $100	$100 to $1000		

pH MEASUREMENT

By RAYMOND BUENGER, Beckman Instruments, Inc.

The instrument man with an automatic pH installation should know the principle of operation, the circuit, and the trouble-shooting procedure.

THOUSANDS of automatic pH installations are now in operation, and most instrument men should become familiar with the equipment and problems associated with the measurement of pH. Let us first consider the four main factors involved in making a typical automatic pH installation for industrial process control.

First are the chemical problems. The chemist must know how the pH of the solution affects the process; how closely the pH must be controlled to maintain operating efficiency, minimum consumption of chemicals, and quality of product; at what steps in the processing operation the pH should be measured; and what chemicals should be added to adjust the pH for optimum operation.

Second are the engineering problems. The engineer must know what kind of equipment is necessary to give proper pH control and where the equipment should be located. Careful study and consideration must be given to temperature and pressure, and to the chemical properties of the solution under test. At this stage the decision generally is made as to whether the pH will be automatically controlled as well as automatically measured and recorded.

Third are the instrument problems. The instrument man must keep the pH equipment operating satisfactorily. He must be familiar with the equipment and must fully understand how it operates. In case of improper operation, he must be able to trouble-shoot and repair the complete installation.

Fourth are the maintenance problems. The maintenance man must make periodic checks of the equipment to see that it is operating properly. He also standardizes the pH instrument with buffer solutions and maintains the electrodes. In smaller companies the duties of instrumentation and maintenance often are combined. This article is on the instrument maintenance problems.

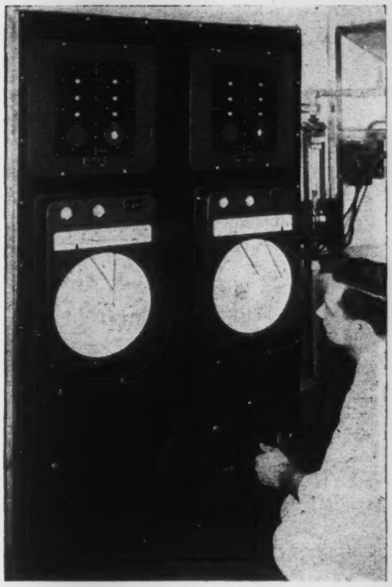
DEFINITION

pH is a measure of the acidity or alkalinity of a solution. pH measures the *strength* of an acid; it does not necessarily measure the *concentration*, or amount, of the acid. For example, weak acids such as acetic (vinegar) can be added in moderate amounts to many solutions without radically affecting the acidity. Similar amounts of strong acids, like sulfuric, when added to the same solutions, can cause a large change in acidity. This is because the strength or weakness of an acid depends on the extent of dissociation (ionization) of the acid to give hydrogen ions. The greater the ionization of the acid, the more the hydrogen-ion concentration, and the greater the acidity of the solution. pH is a measure of hydrogen-ion concentration.

THE pH SCALE

The pH scale is a convenient logarithmic expression of hydrogen-ion concentration. Pure water has a hydrogen-ion concentration of 10^{-7} grams per liter. Thus, on the pH scale (Fig. 1), pH 7 is neutral, lower numbers indicate greater acidity and higher numbers less acidity (greater alkalinity). For practical purposes the pH scale is from 0 to 14 because solutions with pH values above or below this range rarely are encountered. It is important to note that a pH change of one scale unit means an acidity change by a factor of ten. Thus a solution of pH 4 is ten times as acid as one of pH 5, and one hundred times as acid as a solution of pH 6. A small error in pH value, therefore, can mean a large error in acidity.

The earliest method of determining acidity or alkalinity utilized certain organic compounds which changed color with change in pH. Although this method is still used in some laboratories for approximate pH estimations, it cannot be adapted to continuous pH measurement or to automatic pH control. Only through the development of the "electrometric" method has modern pH control become possible.



Typical panel board showing two complete pH installations used in the pH control of soybean protein extraction and precipitation. Beckman multiple-electrode switches are at top of panel; in the center are two Bristol circular-chart recorders; at the bottom are Beckman model RX nonindicating pH amplifiers.

THE ELECTROMETRIC METHOD

The electrometric method of pH measurement is based on the fact that a suitable electrolytic cell immersed in a solution develops a voltage which is directly related to the pH of the solution. By amplifying and measuring this voltage, the exact pH of the solution can be read directly from a meter scale and recorded on a chart. Modern pH meters operate in this manner. The electrolytic cell used consists of two electrodes—a measuring electrode and a reference electrode.

A number of electrodes have been employed during the development of modern pH measuring equipment, but the electrodes which are now universally accepted for pH measurements are the pair comprising a glass electrode and a calomel electrode (Figs. 2 and 3). In 1925 it was shown that when a thin-wall glass bulb containing both an internal solution and a metallic electrode was immersed in an aqueous solution, the electric potential developed across the glass membrane was dependent only on the difference in hydrogen-ion concentration of the solutions on the two sides of the glass membrane. It was possible to measure this difference in potential by connecting the glass electrode to a sensitive galvanometer, completing the circuit with a reference electrode also immersed in the sample solution and connected to the galvanometer.

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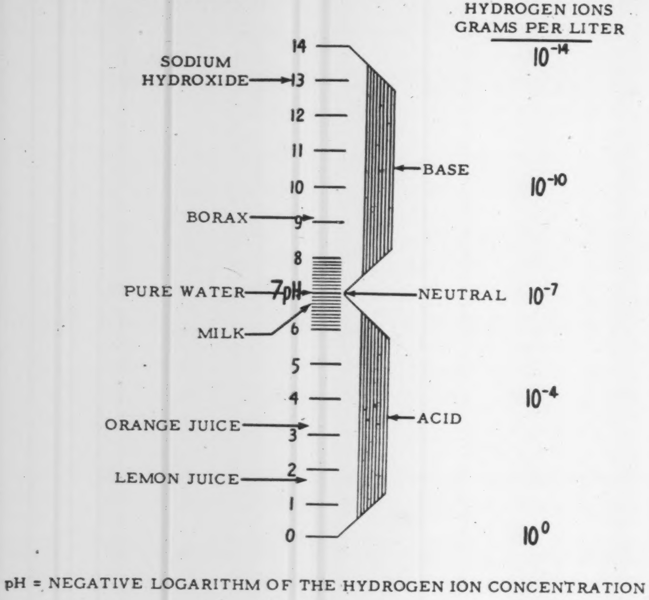
Fig. 1. The pH Scale.


HYDROGEN IONS GRAMS PER LITER
14
SODIUM HYDROXIDE
13
12
11
10
BASE
BORAX
9
8
PURE WATER
7pH
NEUTRAL
MILK
6
5
4
ORANGE JUICE
3
ACID
LEMON JUICE
2
1
0
10^-14
10^-10
10^-7
10^-4
10^0
pH = NEGATIVE LOGARITHM OF THE HYDROGEN ION CONCENTRATION

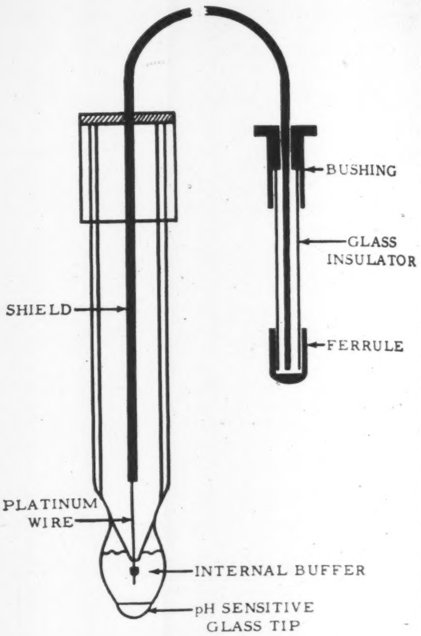

BUSHING
GLASS INSULATOR
SHIELD
FERRULE
PLATINUM WIRE
INTERNAL BUFFER
pH SENSITIVE GLASS TIP

Fig. 2. Sensitive glass-electrode.

In practice, the use of the galvanometer required the resistance across the glass membrane to be as low as possible. This unfortunately resulted in a glass electrode with a large and thin bulb. The fragility of the glass electrode, together with the general unsuitability of the galvanometer, held pH instrumentation in check until the development by Dr. Beckman of the first portable glass-electrode pH meter. This development opened the way to modern pH meters and the rugged Beckman glass electrode.

CIRCUITRY

Fig. 4 shows various circuits which can be used to measure pH. In the slide-wire pH meter, the galvanometer is replaced by an electronic amplifier and a rugged null-indicating meter. A standardized current is maintained in the slide wire, which is moved mechanically until the *IR* drop produced across the slide wire exactly balances the electrode emf., as shown by the null-balance indication.

The most common measuring technique is the feedback pH meter (Fig. 4). The input to the amplifier is the voltage difference between the sensitive-electrode potential and the *IR* drop across feedback resistor *R*. As the *IR* drop is opposed in polarity to the input signal from the glass electrode, this is negative feedback, which establishes a nicely linear relation between electrode emf. and pH. This relationship is shown in Fig. 5. In practice, the feedback resistor is a resistance thermometer that provides both negative feedback and automatic temperature compensation simultaneously.

It should be noted that the function of the pH meter is to amplify current (power) and not voltage. The output voltage is commonly of the same order of magnitude as the input voltage, but the output current is a million to a billion times greater than the input current. This is the first important requirement of a good pH meter. It must measure the potential across the electrodes but must not draw current from them. The second important requirement is that the high-impedance side of the circuit be well insulated from ground to eliminate any electrical leakage.

NEGATIVE-FEEDBACK AMPLIFIERS

The negative-feedback amplifier is a commonly-used means of measuring pH in industrial installations. Fig. 6 shows a simplified diagram of the circuit of the "Beckman Model R pH Indicator," a typical automatic instrument. The amplifier consists of 3 tubes. Tubes P-1 and P-2 are specially processed tubes. The necessary grid, screen, and plate voltages are supplied to the tubes from a voltage divider controlled by a voltage regulator (not shown).

Assuming the instrument covers the pH range 7 to 14, the first step of operation is to balance the meter to read 7 pH with input terminals short-circuited. When the voltage across the electrode is 0 mv., the current through the milliammeter is zero current, or 7 pH. This is the same as having the reference and glass electrodes short-circuited. This adjustment is performed internally in the "Beckman Model R pH Indicator" by setting the selector switch to the No. 2 position, and balancing the meter needle at 7 pH (zero current) by adjusting the screen bias on the P-1 tube.

Let us now apply a voltage from the electrodes. As this is a 7 to 14 pH meter, let us assume that the electrodes are immersed in an alkaline solution of pH 10. With the temperature at 25 deg. C. the voltage across the electrodes is 3 x 59.15 mv., or 177.45 mv. The grid of P-1 is now more negative; the grid of P-2 is more positive; the grid of P-3 is more negative and its plate is more positive. Current flows through the meter and series resistors. The voltage drop across the feedback resistor (the resistance thermometer) is in opposite polarity to the electrodes so that the change on the grid of P-1 is equal to the difference between the electrode emf. and the feedback-resistor *IR* drop.

The feedback resistor is a resistance thermometer whose function is to register the temperature of the sample solution and, by changing resistance with change in temperature, to compensate automatically for the effect of temperature on the emf. of the glass and

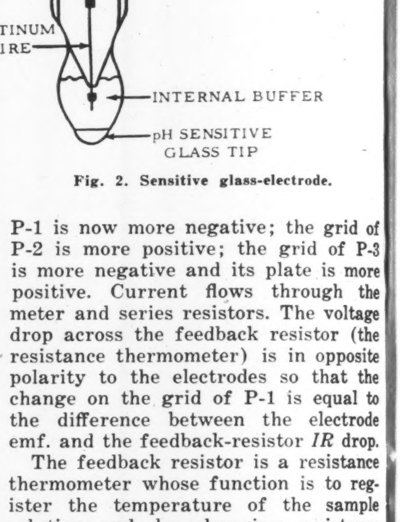
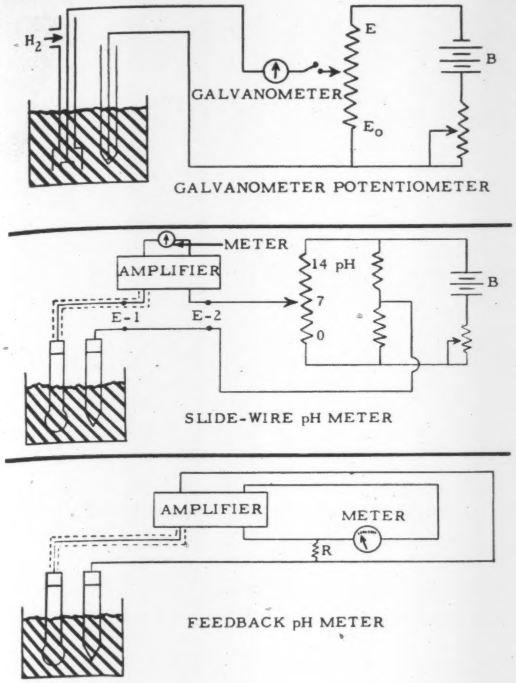

KCl SOLUTION
CONNECTING WIRE
CALOMEL-MERCURY MIXTURE
GLASS WOOL
INTERNAL LIQUID JUNCTION
POROUS FIBER
EXTERNAL LIQUID JUNCTION
Fiber Type
GROUND GLASS SLEEVE
EXTERNAL LIQUID JUNCTION
Sleeve Type

Fig. 3. Reference calomel-electrode.

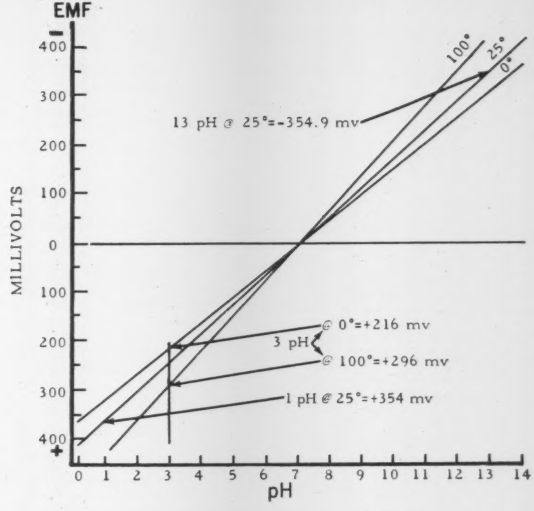


H2
GALVANOMETER
E
B
Eo
AMPLIFIER
METER
14 pH
7
0
E-1
E-2
B
AMPLIFIER
METER
R

GALVANOMETER POTENTIOMETER

SLIDE-WIRE pH METER

FEEDBACK pH METER



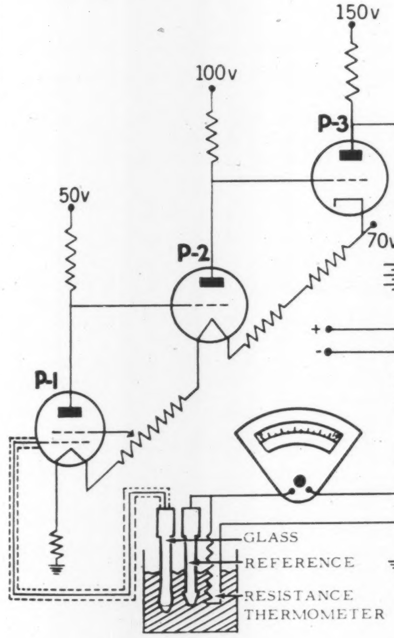
0°C = 54.19 mv/pH
25°C = 59.15 mv/pH
100°C = 74.03 mv/pH

Fig. 4 (top left). Various circuits for measuring pH.

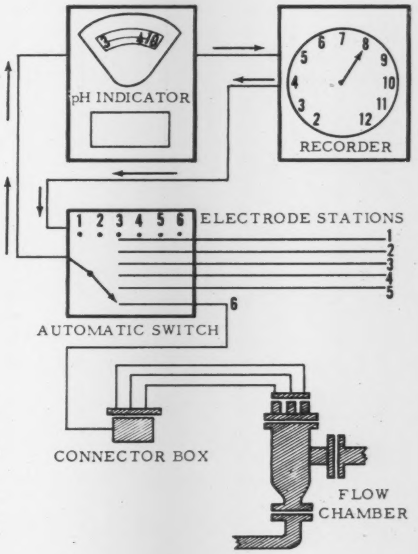
Fig. 5 (top right). Emf.-pH relationship at various temperatures.

Fig. 6 (below left). Simplified circuit diagram of the "Beckman Model-R pH Indicator."

Fig. 7 (below right). Typical pH installation for six stations.



150v
100v
P-3
50v
70v
P-2
90-VOLT BATTERY
+
-
RECORDER TERMINALS
P-1
GLASS
REFERENCE
RESISTANCE THERMOMETER



pH INDICATOR
RECORDER
1 2 3 4 5 6
ELECTRODE STATIONS
1
2
3
4
5
6
AUTOMATIC SWITCH
CONNECTOR BOX
FLOW CHAMBER

reference electrodes. The resistance thermometer thus determines the sensitivity of the amplifier, or the millivolts per pH on the meter scale.

The recorder terminals are across a portion of a resistor in series with the 1-ma. meter so that the current through the meter determines the voltage drop across this resistor. If, for example, the recorder required 500 mv. full scale, this resistor would be 50 ohms because

50 ohms x 0.001 amp = .050 volt

On the "Beckman Model R pH Indicator" a plug-in resistor is used.

Negative feedback is used because errors due to nonlinear tube-characteristics are eliminated and output current is accurately linear with respect to the input voltage.

A COMPLETE pH INSTALLATION

Fig. 7 shows a typical pH installation. It is possible to connect six electrode pairs to a single automatic pH indicator if a six-point manual or automatic switch is used with a six-point recorder.

In many installations the electrode stations are a long distance from the pH measuring equipment. For such remote installations it is desirable to have extra multiconductor cable and a connector box rather than to have longer leads from each electrode to the pH instrument. The maximum distance between the electrodes and the pH indicator generally should not be over 200 feet.

The first step in preparing for operation of a complete pH installation is to immerse each set of electrodes in a buffer solution of known pH and to ad-

Continued on page 632

Indirect Process Control by SERVOMECHANISM

By ROBERT G. DURNAL
Westinghouse Electric Corp.

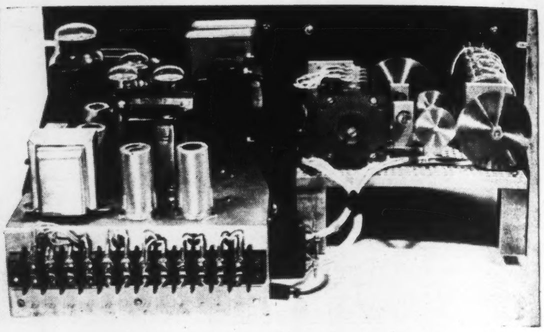


Fig. 1. Servomechanism for controlling wire temperature by control of current which varies as the third power of temperature.

The electromechanical servomechanism can control a process by an indirect variable which is a linear (but not straight-line) function of the main process variable.

IN most industrial processes, the method of control involves the measurement of some fundamental variable of the process, and regulation of the process input to hold this variable within prescribed limits. If the variable to be controlled is such that measurement of it is difficult or impossible, other means of processes control must be employed.

The general method of procedure in such a case is to relate the fundamental variable to some other system variable, and regulate the process input to control this second variable. In order to avoid confusion, the fundamental variable is called the *process variable*, whereas the related system variable is called the *indirect variable*.

If the process input is in the form of electrical energy, or if the input measurables can be converted to electrical signals, the indirect variable can be expressed as an electrical quantity, and often will be of the form

$$u = V\bullet f(I), \qquad (1)$$

where u is the indirect variable, V the voltage applied to the process, and $f(I)$ some more or less complicated function of the process current. The indirect variable, u, can be related to the process variable by some expression of the form

$$u = g(X), \qquad (2)$$

where $g(X)$ is a function (preferably simple) of the process variable, X. The functions $f(I)$ and $g(X)$ are assumed to be single-valued.

The problem can now be broken into one of generating the indirect variable (u) from the voltage and current, and controlling it by regulating the electrical energy supplied to the process.

ADDING LOGARITHMS

One way of generating the indirect variable (u) that suggests itself immediately is to add the logarithms of V and $f(I)$. Such a system is shown in block diagram form in Fig. 2. Logarithmic devices are available for either a-c. or d-c. operation. This method has the advantage that if u is of the form

$$u = V\bullet KI^n, \qquad (3)$$

it is not necessary to generate the function $f(I)$ because $\log I^n$ is obtained from $\log I$ by inserting a simple scaling factor. Disadvantages in this system are instability and inaccuracy in the logarithmic devices.

USE OF POTENTIOMETER

Another method of generating u is to make use of the multiplicative property of an ordinary potentiometer. If the voltage V is impressed across the outside terminals, the voltage at the arm will be

$$E = V\bullet\theta/\theta_{\max.}, \qquad (4)$$

where θ is the rotary position, and θ max. the maximum value of rotation. If the rotation is then made proportional to $f(I)$, we have

$$\theta/\theta_{\max.} = f(I)/f(I)_{\max.}, \qquad (5)$$

and the voltage at the arm will then be

$$E = Vf\,(I)/f(I)_{\max.}, \qquad (6)$$

which is of the desired form.

In order to make θ proportional to $f(I)$, we need a positional servomechanism with a nonlinear position-sensing element. Fig. 3 shows a simple position servo. The amplifier and motor operate to make the voltage at point A equal to the input voltage. If the position-sensing potentiometer is linear, then the angle θ will be proportional to the input. If, however, the potentiometer is wound so that

$$R = K\phi(\theta), \qquad (7)$$

the balance in voltage between point A and the input will be at an angle

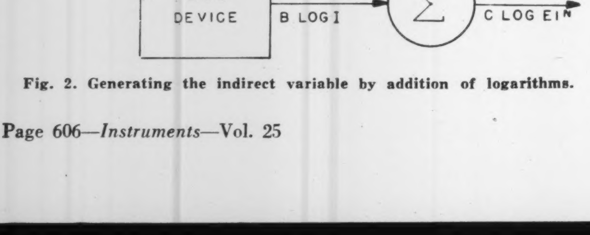


Fig. 2. Generating the indirect variable by addition of logarithms.

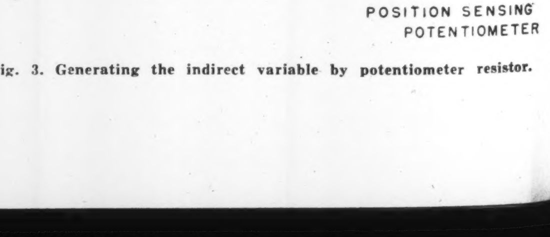


Fig. 3. Generating the indirect variable by potentiometer resistor.

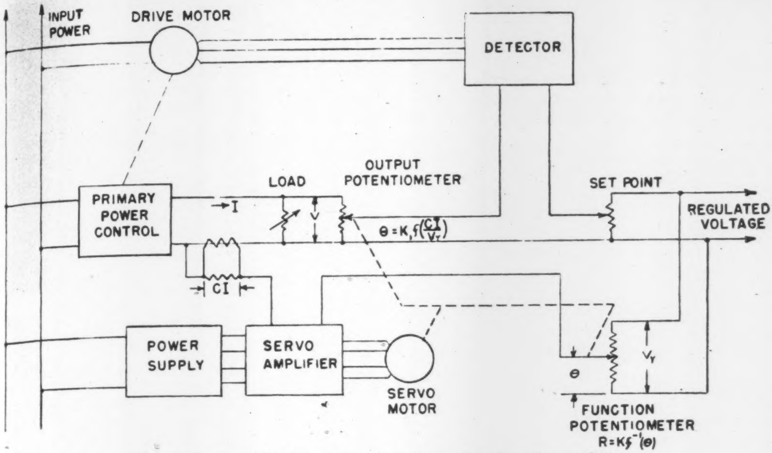

INPUT POWER
DRIVE MOTOR
DETECTOR
PRIMARY POWER CONTROL
LOAD
OUTPUT POTENTIOMETER
I
V
$\theta = K_1 f(\frac{CI}{V_r})$
SET POINT
REGULATED VOLTAGE
CI
POWER SUPPLY
SERVO AMPLIFIER
SERVO MOTOR
θ
V_r
FUNCTION POTENTIOMETER
$R = K f^{-1}(\theta)$

Fig. 4. Servomechanism using function potentiometer resistor.

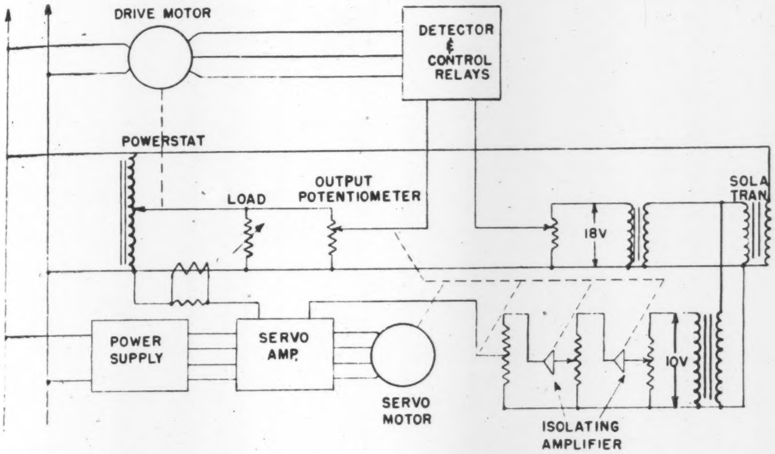

DRIVE MOTOR
DETECTOR & CONTROL RELAYS
POWERSTAT
LOAD
OUTPUT POTENTIOMETER
SOLA TRAN
18V
POWER SUPPLY
SERVO AMP
SERVO MOTOR
10V
ISOLATING AMPLIFIER

Fig. 5. Circuit for wire-temperature control.

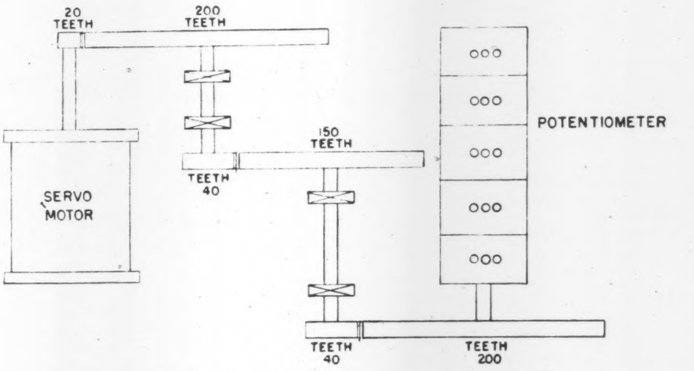

20 TEETH
200 TEETH
150 TEETH
TEETH 40
SERVO MOTOR
POTENTIOMETER
TEETH 40
TEETH 200

Fig. 6. Component layout for servomechanism.

such that

$$\theta = K_1\phi^{-1}(CI)/(Vr) \qquad (8)$$

where the ϕ^{-1} denotes a function which is the inverse of the direct function. If we make ϕ the f^{-1} function, then we will have

$$\phi = K_1 f\ (CI)/(Vr) \qquad (9)$$

which is of the same form as (5), and generates the desired function.

A disadvantage of this system is that the gain of the servo changes throughout the operating range. The gain at any input I_1 can be expressed as

$$A = K_s \cdot \left.\frac{df^{-1}(I)}{dI}\right|_{I_1} \qquad (10)$$

that is, the gain is proportional to the derivative of the f^{-1} function evaluated at the point I_1. There is an optimum gain for any servo system. If the gain exceeds this optimum by any great amount, the servo becomes unstable; if the gain is much lower than the optimum, accuracy and speed of response are sacrificed. Therefore, we must impose a restriction that the change in slope of the f^{-1} function be not too great over the operating range.

A similar method of generating the indirect variable, in which the servo gain remains constant, involves a linear position-sensing potentiometer resistor. Here we have

$$\phi = K_2 I \qquad (11)$$

The function u is generated by using a nonlinear output pot resistor. It is wound in such a way that

$$R = K_3 f(\theta) \qquad (12)$$

giving the voltage at the arm of

$$E = K_3 V f(K_2 I) \qquad (13)$$

which is also of the form (5).

It is advisable to use the method which involves the function with least change in slope for the nonlinear potentiometer resistor.

Fig. 4 shows a diagram of the first of these two systems. Although it may not be obvious, there is an implied restriction that the speed of response of the main power control and the servo must not be nearly the same, or the system is liable to oscillate. A relatively simple precaution is to make the main power control a fairly slow-response device.

A TYPICAL APPLICATION

An application of such a controller is now discussed. It was desired to hold a wire at constant temperature in a vacuum while the material of the wire is evaporated from the surface. Assuming radiation only from the surface of the wire and no other heat losses, the indirect variable becomes

$$u = V\cdot\sqrt[3]{I} = g(T) \qquad (14)$$

The inverse function $f^{-1}(I)$ now becomes I^3.

The circuit of Fig. 5 was used to regulate this process. As no special pot resistors were available, the cube function was obtained by cascading three linear pot resistors through isolating amplifiers. The cube-root shaft rotation then was used to perform the multiplication required in the indirect variable.

The primary power control was a Superior Electric "Powerstat" which required 45 seconds to be driven over its complete range. The actual servo layout, as shown in Fig. 6, had a runaway velocity of approximately 10 rpm., and no interaction resulted. Although the servo had infinite gain at zero current, the operating range was chosen as a 100 to 1 variation in current, giving a gain at minimum current of 22 times the gain at maximum current. This leaves something to be desired in the way of servo performance, and indicates that a linear servo would be advantageous.

Owing to the nature of the indirect variable, the error will be greatest at low values of I. The first unit built has an inherent error of 5 percent at the lower end, and less than ½ percent at the upper end. Fig. 1 shows the completed unit.

INSTRUMENT ELECTRONICS

By MILTON H. ARONSON
Technical Editor, *Instruments*

Three new solid-state amplifiers—the magnetic amplifier, the dielectric amplifier, and the transistor—may displace electron tubes in many instrument applications.

CHAPTER IX. SOLID-STATE AMPLIFIERS

ALTHOUGH new applications for electron tubes are found every day, there is much interest in three newer devices which can perform many of the functions of electron tubes, and which are superior to tubes in ruggedness and life expectancy. These devices are (1) the magnetic amplifier, (2) the transistor, and (3) the dielectric amplifier.

The term "solid state" can be applied to these devices because they are solids, and the controlled current flows through the solids. As they have no filaments to burn out, and as they are solids, the devices are rugged and long lived. Hence the instrument man, who always is seeking for more rugged and longer-lived devices, is particularly interested in these devices.

MAGNETIC AMPLIFIER

The magnetic amplifier is simply an inductor whose reactance is controlled by core permeability. The most common type magnetic amplifier controls the reactance of a main winding by controlling the *saturation* of its core. This type amplifier, often called a *saturable reactor*, is built like a transformer (Fig. 9-2). The *control winding* controls the core saturation, which in turn controls the reactance of the main winding. The load is in series with the main, or load, winding and the a-c. high-power source. When the core is saturated, only the d-c. resistance of the coil wire impedes the current and maximum current flows. As a large current through the load can be controlled by a relatively weak current in the control winding, the device is an amplifier.

There are two load windings, so wound that the flux lines produced by load current cancel in the control leg of the core. This is necessary to prevent output-signal variations (load current) from influencing the control-winding action. Thus the control winding can control the load current without the load current influencing the control winding. If this were not done, large power (high current) would be required in the control winding, and the device would be an inefficient amplifier.

ANSWERS TO QUIZ VIII.—AMPLIFIER CIRCUITS (Part 2)

8-24.	(c)	8-27.	(b)	8-31.	(b)	8-34.	(a)	8-38.	(b)
8-25.	(a)	8-28.	(d)	8-32.	(b)	8-35.	(d)	8-39.	(a)
8-26.	(c)	8-29.	(c)	8-33.	(c)	8-36.	(d)	8-40.	(c)
		8-30.	(d)			8-37.	(b)		

Test items for IX.—Page 654

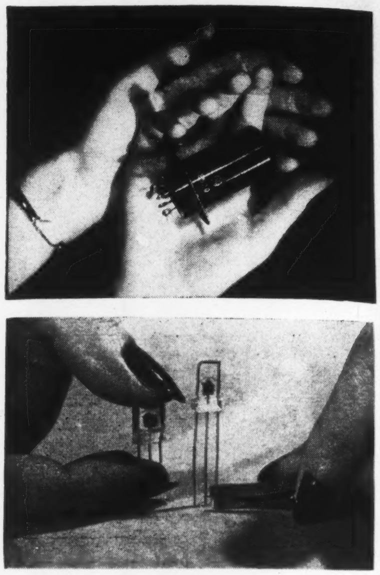


Fig. 9-1. GE magnetic amplifier used for amplifying weak d-c. signals by converting them into an 800-cps. second-harmonic signal; bottom, RCA developmental transistor.

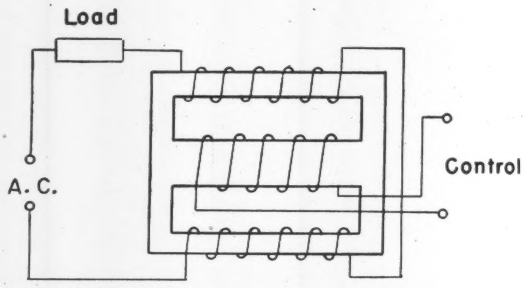


Fig. 9-2. Three-legged saturable reactor and symbol.

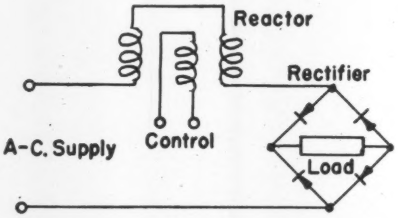


Fig. 9-3. Saturable-reactor circuit with d-c. output to load.

The alternating current through the load can be rectified into direct current when it is desired to have both d-c. input and d-c. output. This usually is done by metallic-plate rectifiers in a bridge circuit, as shown in Fig. 9-3.

Feedback

A portion of the rectified output often is fed back to an additional winding on the control leg of the core, as in Fig. 9-4. The feedback can be positive or negative—that is, the signal fed back can be in phase (positive feedback) or 180 degrees out of phase (negative feedback) with the signal in the control winding.

Positive feedback causes high sensitivity of action; only a minute control current is required to saturate the core because the amplified feedback signal causes quick core saturation. Thus positive feedback results in high gain and rapid *self-saturation*.

Negative feedback results in typical degenerative action reduced gain and increased linearity. That is, the output current is a more linear function of input current, and a given change in input current causes less change in output current. Fig. 9-4,B shows a useful way for representing the magnetic amplifier symbolically. Note that the load coils can be connected in series or parallel—provided their flux lines cancel in the control leg.

Core Material

When the core is not saturated, the reactance of the load windings is high and small current flows. In a magnetic amplifier the core is driven into saturation by a d-c. signal applied to the core winding so that a large current can flow in the load windings. Thus a core which saturates easily is required. Other desirable core features are (1) eddy currents should be small, (2) hysteresis loss should be small, (3) the physical mass of the core should be small, and (4) the retentivity and coercive force of the core should be low.

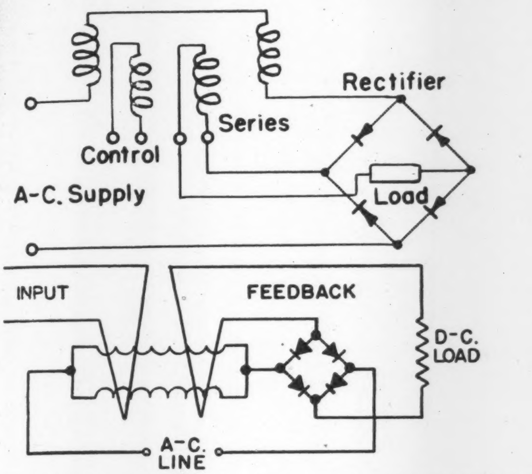


Fig. 9-4. Saturable-reactor circuit with d-c. output and series feedback on control leg.

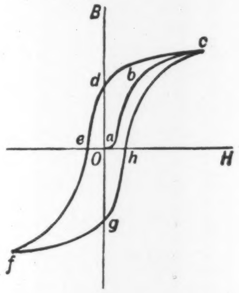


Fig. 9-5. Hysteresis loop.

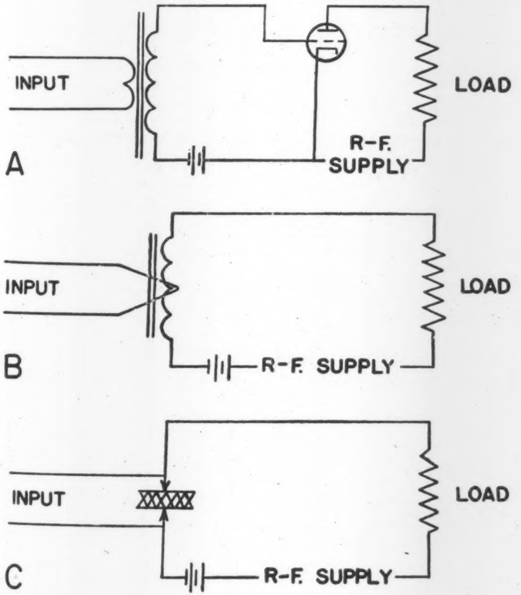


Fig. 9-6. Comparison of analogous amplifier circuits. A, electron tube; B, magnetic amplifier; C, dielectric amplifier.

A *hysteresis* curve of a metal (Fig. 9-5) is made by plotting the field strength in the metal (B) caused by a given field strength in air (H). The ratio B/H at any point is the permeability (μ) of the metal. When H is first increased and then decreased, B changes along path a-b-c-d-e-f-g-h. The closed curve is known as a hysteresis loop. Note that when H first increases from O and then comes back to O, the metal remains magnetized by amount Od. This is the *retentivity* of the metal. The magnetizing field (Oe) necessary to demagnetize the metal is called the *coercive force*.

A good core material for a magnetic amplifier should have a sharply rectangular shape with small enclosed area—that is, both the coercive force and retentivity should be small. The sides should be steep and the "knee" sharp. Materials with such good characteristics are "Mu Metal," "AEM 4750," "Permenorm 5000-Z," "Hipernik," "Permalloy," and "Supermalloy."

Time Constant and Supply Frequency

If a constant-value d-c. voltage is applied suddenly to the control winding of a magnetic amplifier, the output of the amplifier rises exponentially to its final value. The *time constant*, or *characteristic time*, of the amplifier is the time required for the output to reach 63 percent $(1 - 1/\epsilon)$ of its final value. This time constant is inversely proportional to the frequency of the power source, but increases with the gain of the amplifier; it is not dependent on the core material.

A close analogy can be made between a magnetic amplifier and an electron tube with an a-c. plate supply, as shown in Fig. 9-6. An a-c. plate supply is required because the magnetic amplifier operates only with alternating current. As the "B" supply is an a-c. supply, the frequency of the signal to be amplified must be less than that of the supply. In other words, the supply frequency should be at least 3 times that of the highest frequency in the signal to be amplified. This is necessary because the amplifier is essentially an on-off switch, permitting current to flow only for intervals. A 60-cps. supply is adequate for d-c. signals from photoelectric cells, thermocouples, etc.; an r-f. supply is required for signals of high frequency. This supply usually is an electron-tube circuit that is no more complicated than the rectifier required for conventional electron-tube amplifiers.

Flux Measurement

One important and much-used application of the saturable reactor is for measuring flux and weak magnetic fields. A typical *flux gate* for measuring weak magnetic fields is shown in Fig. 9-7.

Continued on page 648

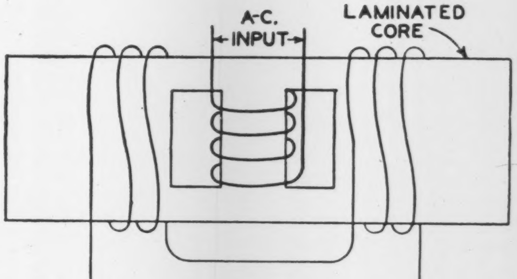


Fig. 9-7. The flux gate.

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INSTRUMENT SOCIETY *of* AMERICA *Journal*

Vol. 8 **MAY 1952** **No. 5**

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by James L. Waters and Nelson W. Hartz

THE MANAGER'S PAGE

Percy V. Jones

SPRING is a word of many meanings, the mere mention of which during the dreary winter gives one a promise of the brighter days to come. It brings a vision of the season when plants begin to grow and the dormant world experiences its annual awakening. Another meaning is "to rise up suddenly," and this more accurately describes what has happened to the Instrument Society of America since last September.

Something new has been added to ISA. By that we do not only refer to the three new Sections—Carolina Piedmont (48 members), Central Ohio Valley (32 members), and Permian Basin (54 members)—but particularly to the 726 new members who have been brought into existing Sections.

It is realized that figures, and especially statistical figures, are pretty boring to most people. However, your editor happens to like figures because they tell a story, in this case, a very interesting and stimulating one, a story that shows the results of the time and effort on the part of the many Members who have built ISA into a dynamic organization within a period of seven months.

SOCIETY GROWTH SINCE 1947

A tabulation of the record of Society growth since 1947 shows that past increases in membership were due very largely to the members brought in by new Sections. An outstanding example of this is the twelve month period 8/1/47-8/1/48, during which time membership increased by 984 or 43 percent. During that period, however, ten new Sections were responsible for 592 members, so that the increases in membership in existing Sections was 392, or 17 percent.

The thirteen month period 8/1/48-9/1/49, brought 600 new members to the Society for an 18 percent gain. Four new Sections accounted for 239 of these members and 7 percent of the increase. The following twelve months saw the addition of eight new Sections, which accounted for 401 of the 418 new members added during that period. Thus, growth of membership in existing Sections, at that time, accounted for less than ½ percent of the total for that period.

The period 9/50-9/51, added 251 new members, 51 from one new Section, which accounted for 1 percent of the 6 percent increase.

The latest count of membership, as of March 31, 1952, tabulated to include the percent of change by Sections, as compared with September 1, 1951, has a different story to tell. This shows an increase of 19 percent or a total of 865 new members. Of this total, new members added to existing Sections accounted for 726 or 85 percent of the total increase.

Thus, the Society has experienced a very healthy growth through the addition of three new Sections. But, of more importance to the future of the Society, is the vitality of existing Sections. Although seven Sections had minor decreases and two show no change, the over-all picture is such that congratulations are in order for those many Members who have given of their time and effort to make ISA a stronger and more vital organization. It is hoped that the outstanding record made by many Sections will serve as a stimulus to others to go and do likewise.

ROLE OF LOCAL SECTIONS

The National Office receives letters almost every week from instrument men seeking information about the Society and asking how they can form

National Committees and Chairmen

Society Structure & Planning—Nelson Gildersleeve.
Nominating—G. F. Akins
Constitution, Rules & Procedures—R. L. Galley
Instrument Industry—Charles L. Saunders
Finance—J. T. Vollbrecht
Meetings and Exhibits—E. J. Grace, Jr.
Publications—C. W. Covey
Sections and Membership—M. D. Shriver
Employment—P. V. Jones
Intersociety Relations—Everett S. Lee
Public Relations—Douglas M. Considine
Government Relations—Ralph L. Goetzenberger
Educational Committee—Prof. Robert J. Jeffries
Historical—L. M. Susany
***Technical Program**
***Research and Development**
Instrument Operation & Maintenance
J. Johnson
Testing Instrumentation—D. C. Little
Analysis Instrumentation—Axel H. Peterson
Instrumentation for Inspection & Gaging
W. A. MacCreahan
Instrumentation for Production Processes
W. H. Brand
Instrumentation for Transportation
F. H. Catlin
Medical Instrumentation—Dr. H. J. Morowitz
Meteorological Instrumentation
Christos Harmantas
Radiation Instrumentation—Richard W. Johnston
Geophysical Instrumentation—Dr. David Muzzey
***Physical Properties Measurement**
Acronautic Instrumentation—Robert Tozier
Recommended Practices—A. V. Novak

**Chairman not assigned*

ISA MEMBERSHIP REPORT 4/1/47-3/31/52

Section	*Charter Date*	4/1/47	8/1/47	8/1/48	9/1/49	9/1/50	3/30/51	9/1/51	3/31/52	*Percent Change* (9/1/51-3/31/52)
Akron	7/19/48			14	43	36	35	30	35	17
Albuquerque	7/16/49					59	47	46	45	-2
Aruba	1/24/47	26	28	64	59	39	42	41	39	-5
Atlanta	8/23/48			16	20	17	20	24	43	79
Baltimore	1/10/46	60	60	63	69	76	80	81	104	28
Baton Rouge	5/10/49					47	45	23	20	-13
Boston	7/28/48				86	105	121	121	130	7
California	1/10/46	31	47	103	164	167	173	174	216	24
Carolina Piedmont	1/18/52								48	..
Central Illinois	3/ 8/48			26	30	36	39	33	33	0
Central Indiana	1/30/47	65	81	82	78	80	78	77	85	10
Central New York	5/15/50					18	31	31	31	0
Central Ohio Valley	3/27/52								37	..
Charleston	1/10/46	112	91	80	81	68	63	65	84	13
Chicago	1/10/46	232	245	270	299	342	336	321	347	8
China Lake	1/17/49				86	41	41	24	22	-8
Cincinnati	3/ 7/47	39	43	58	65	62	68	66	79	20
Cleveland	1/10/46	110	119	127	122	129	134	122	137	12
Columbus	7/16/49					26	23	22	23	5
Cumberland	4/24/46	27	31	19	15	14	18	20	23	15
Denver	7/26/51							51	72	41
Detroit	1/10/46	82	83	79	75	65	64	59	62	5
Eastern New York	1/20/47			58	90	98	89	87	101	16
Gulf Coast	1/10/46	26	28	46	42	41	39	34	54	59
Houston	3/16/48			82	113	134	141	147	189	29
Kansas City	1/10/46	36	38	49	53	57	68	74	69	-7
Louisville	3/ 7/47	41	53	38	39	37	47	45	56	24
Montreal	6/16/48			38	72	82	75	77	94	22
New Jersey	1/10/46	133	146	189	227	232	270	280	322	15
New Orleans	4/11/46	5	9	9	4	10	11	9	7	-12
New York	1/10/46	122	132	150	214	250	272	261	276	6
Niagara Frontier	7/31/47		48	120	90	91	94	99	142	43
North Texas	2/16/49				40	24	21	13	15	11
Northern California	9/10/49					102	99	94	106	12
Northern Indiana	1/10/46		21	28	23	26	44	45	57	27
Oak Ridge	8/27/46	67	69	55	67	66	74	76	89	17
Ontario	1/10/46	65	61	39	43	41	44	44	37	-16
Panhandle	2/10/50					45	49	39	48	23
Permian Basin	12/ 2/51								54	..
Philadelphia	1/10/46	242	263	328	381	330	340	339	358	6
Pittsburgh	1/10/46	152	157	185	219	241	247	238	270	13
Presque Isle	7/31/47		2	24	22	18	20	20	24	20
Richland	1/ 1/48			124	99	72	95	107	162	51
Rochester	2/16/48			60	67	77	88	88	92	5
Sarnia	9/ 1/47			99	77	77	77	85	110	29
South Bend	3/ 7/47	21	27	23	10	0	0	0	0	0
South Michigan	11/11/46	42	51	45	34	26	29	27	28	4
South Texas	11/11/46	86	50	42	46	61	69	69	74	7
St. Louis	1/10/46	68	79	82	112	132	126	114	123	8
Tennessee	1/10/46	36	23	40	41	46	45	50	58	16
Toledo	4/15/50					27	40	42	50	19
Tulsa	9/ 6/47			75	82	96	92	107	131	22
Twin Cities	3/10/47		11	46	44	36	40	43	45	5
Washington	1/10/46	121	141	134	143	116	128	134	149	11
Wayne County	1/10/46	40	41	42	45	73	95	89	169	90
Wilmington	12/ 2/49					77	85	90	102	13
At Large					27	28	46	52	38	-27
TOTAL MEMBERS		2121	2296	3280	3880	4298	4557	4549	5414	19

local Sections. These men are encouraged and assisted in every way by the National Office and the Sections and Membership Committee. The number of Sections will continue a natural growth as the fame of the Society spreads through its published technical papers, Recommended Practices, motion picture, National Instrument Conferences and Exhibits, Regional Conferences, and Section activities. Only the local Sections, however, can keep the members thus attained by maintaining the continued interest of their membership. The job is two-fold—to get new members and to keep old members.

Let us not set our sights too low when looking at the Society's future. Last year's goal of 5000 is well exceeded, and a membership of 6000 by next September is well within the realm of possibility.

Every member can play a part in making possible the attainment of this goal by inviting friends to Section meetings and urging them to join the Society. Many instrument men do not know of the Society, and others need only to be asked to join. Your local membership chairman or the National Office will be happy to supply application blanks or any information desired.

SECTIONS AND MEMBERSHIP REPORT
8/1/46 — 3/31/52

Date	*Number of Members*	*Number of Sections*
8/46	1075	21
12/46	1650	23
4/47	2121	27
8/47	2296	32
3/48	2966	38
8/48	3280	41
3/49	3762	44
5/49	3908	44
9/49	3880	47
1/50	4224	49
6/50	4300	52
9/50	4298	52
3/51	4557	52
9/51	4549	52
3/52	5414	55

MEMBERSHIP RECORD BY SECTIONS, BY GRADE

Sections	*FM**	*AM*	*SM*	*Total*
Akron	34		1	35
Albuquerque	30	15		45
Aruba	39			39
Atlanta	42	1		43
Baltimore	100	4		104
Baton Rouge	19	1		20
Boston	130			130
California	216			216
Carolina Piedmont	47		1	48
Central Illinois	32	1		33
Central Indiana	31	53	1	85
Central New York	31			31
Central Ohio Valley	37			37
Charleston	80	4		84
Chicago	242	18	87	347
China Lake	21	1		22
Cincinnati	78	1		79
Cleveland	135	2		137
Columbus	18	4	1	23
Cumberland	21	2		23
Denver	72			72
Detroit	58	4		62
Eastern New York	72	1	28	101
Gulf Coast	47	7		54
Houston	181	5	3	189
Kansas City	57	12		69
Louisville	48	7	1	56
Montreal	91		3	94
New Jersey	321	1		322
New Orleans	7			7
New York	213	10	53	276
Niagara Frontier	115	21	6	142
North Texas	15			15
Northern California	106			106
Northern Indiana	52	3	2	57
Oak Ridge	89			89
Ontario	37			37
Panhandle	48			48
Permian Basin	53	1		54
Philadelphia	338	13	7	358
Pittsburgh	263		7	270
Presque Isle	21	3		24
Richland	117	6	39	162
Rochester	91		1	92
Sarnia	101	9		110
Southern Michigan	18	9	1	28
South Texas	64	7	3	74
St. Louis	121	2		123
Tennessee	38	18	2	58
Toledo	50			50
Tulsa	128	3		131
Twin Cities	31	11	3	45
Washington	84	65		149
Wayne County	118	48	3	169
Wilmington	100	2		102
At Large	33	4	1	38
Totals	4781	379	254	5414
Percent of Total	88%	7%	5%	100%

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*FM—Full Member AM—Associate Member SM—Student Member

'52 Show Announcement Luncheon

Leading industrial executives in the Cleveland district and members of the National and Local ISA Executive Committee attended a luncheon in the Red Room, Cleveland Hotel, Cleveland, March 24th, 1952, in the honor of Dr. A. O. Beckman, National President. The sponsoring Committee was made up of the following: J. C. McHannan, Chairman, Board of Directors, Central National Bank of Cleveland; L. D. McDonald, Vice-President, Warner & Swasey Co.; W. F. Munford, Vice-President, American Steel and Wire Div., United States Steel Co.; J. L. Myers, President, Cleveland Graphite Bronze Co.; and A. A. Stambaugh, Chairman, Board of Directors, Standard Oil Co. of Ohio.

A. O. Beckman

Fred Lennon

Fred Lennon, President, Crawford Fitting Co., and Chairman of the Cleveland Host Committee for the 1952 Instrument Conference and Exhibit, introduced Dr. Beckman. In his introduction, Mr. Lennon pointed out that Dr. Beckman could enlighten the many of those in management who do not fully realize the large contributions of instrumentation to the operating efficiency of modern industrial plants.

Dr. Beckman outlined the place of instruments in our present economy, and the remarkable growth of ISA since its beginning. He stressed the contributions made by instruments to research and industry, and the important part played by the Instrument Industry.

The industrial executives were also made aware of the many benefits to be derived from having their engineers, scientists, and operating men attend the technical sessions to be held during the Seventh National Instrument Conference and Exhibit.

Dr. Beckman concluded his talk by extending a cordial invitation to those present to visit the "Instrument Show" to be held in the Cleveland Auditorium September 8-12, 1952.

Largest Instrument Exhibit and Conference

The success of the Seventh National Instrument Exhibit is assured by the fact that over 25,000 square feet of exhibit space has been sold up to April 20th, when the editorial copy of the ISA *Journal* went to the printer. The largest number of instrument manufacturers (163) have reserved 245 booths:

Aircraft Marine Products, Inc.
Alina Corp.
Allegany Instrument Co.
American Meter Co.
Ambos Jones Co.
Anderson & Sons, Inc.
Annin Co.
Askania Regulator Co.
Assembly Products, Inc.
Associated Research, Inc.
Automatic Electric Sales Corp.
Automatic Temperature Control Co.
Bacharach Industrial Instrument Co.
Baird Associates, Inc.
Baker Co.
Barton Instrument Corp.
Beckman Instruments, Inc.
James G. Biddle Co.
J. Bishop & Co.
Black, Sivalls & Bryson, Inc.
Bowser, Inc.
Brookfield Engineering Labs.
Brooks Rotameter Co.
Brush Development Co.
Buffalo Meter Co.
Burgess Battery Co.
Burling Instrument Co.
Cameron Iron Works, Inc.
Carboloy Department, GE
Century Geophysical Corp.
John Chatillon & Sons
Chemiquip Co.
Commercial Research Labs.
Conax Corp.
Conoflow Corp.
Consolidated Engineering Corp.
Continental Equipment Co.
Cook Electric Co.
R. W. Cramer Co.
Crawford Fitting Co.
Daniel Orifice Fitting Co.
Daven Co.
Davis Instruments
DeZurik Shower Co.
F. W. Dwyer Mfg. Co.
Eagle Signal Corp.
Edin Co.
Thomas A. Edison, Inc.
Electric Indicator Co.
Esterline Angus Co.
Falstrom Co.
Farris Engineering Co.
Fenwal, Inc.
Fielden Instrument Corp.
Fischer & Porter Co.
Fisher Governor Co.
Foster Engineering Co.
Fulton Sylphon Div., Robertshaw-Fulton Control Co.
General Electric Co.
General Mills, Inc.
Gow-Mac Instrument Co.
Grayhill
Green Instrument Co.
Hammel-Dahl Co.
Hankison Corp.
A. W. Haydon Co.
Hays Corp.
Helicoid Gage Div., American Chain & Cable Co.
Herschede Hall Clock Co.
Hickok Electrical Instrument Co.
Hills McCanna Co.
Hoke, Inc.
Holtzer Cabot Div., National Pneumatic Co.
Imperial Brass Mfg. Co.
Industrial Electronics, Inc.
Industrial Engineering Corp.
Industrial Instrument Corp.
Industrial Instruments, Inc.
Industrial Laboratories Publishing Co.
Industrial Pyrometer & Supply Co.
Industrol Corp.
Instrument Development Labs.
Instruments Publishing Co.
J-B-T Instruments, Inc.
Jerguson Gage & Valve Co.
C. M. Kemp Mfg. Co.
Kieley & Mueller, Inc.
King Instrument Co.
Lapp Insulator Co.
Leslie Co.
Librascope Inc.
Lord Manufacturing Co.
Magnetrol, Inc.
Marine & Industrial Products Co.
Mason-Neilan Regulator Co.
McAlear Manufacturing Co.
Meletron Corp.
Meriam Instrument Co.
Metrotype Corp.
Micro Switch Div., Minneapolis-Honeywell Regulator Co.
Midwestern Geophysical Co.
Milton Roy Co.
Miniature Precision Bearings, Inc.
Mine Safety Appliances Co.
Minneapolis-Honeywell Regulator Co.—Valve Products
Mittlemann Electronics Div., Century American Corp.
Samuel Moore & Co.
Nash Engineering Co.
National Spectrographic Labs., Inc.
New Hermes Engraving Machine Corp.
North American Philips Co.
Nuclear Research Corp.

Continued on page 615

Section Secretaries, Meeting Data and Programs

AKRON
Russell F. Marquardt, 1782 Tonawanda Ave., Akron 5, Ohio. Tel: ST-6865
Fourth Tuesday, Meeting 8:15 P.M., U. of Akron, Ayer Hall, Rm. 212-B.

ALBUQUERQUE
W. E. Bostwick, 304 So. Princeton, Albuquerque, N. Mex.
First Monday, Meeting at 8:00 P.M., Mitchell Hall, Univ. of N. M.

ARUBA
J. L. Lopez P. O. Box 203, c/o Lago Oil & Transport Co. Ltd., Aruba, N. W. I. Tel. 2087.
First Tuesday, 7:30 P. M., Engr's Club.

ATLANTA
M. Virgil Davis, 357 Sixth St., N.W. Atlanta, Ga. Tel. EM. 3042
Fourth Friday, Meeting 7:30 P.M., Electric Bldg., Georgia Power Co.

BALTIMORE
G. B. Greer, 631 East 36th St., Baltimore 18, Md. Tel: CHesapeake 6879
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
G. M. McCarroll, 1813 Edinburgh Ave., Baton Rouge 6, La.
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 7:30 P. M., 99 Club, 99 State St.

CALIFORNIA
Gerald B. Miller, 4622 Halbrent Ave., Sherman Oaks, Calif.
Second Wednesday. Dinner at 6:30 P. M. Meeting at 8:00 P. M.
June 11, joint meeting with Optical Soc. of So. Calif. Tour of new NBS Corona Labs at Norco, Calif., followed by papers describing unclassified phases of work at the labs.

CAROLINA PIEDMONT
L. Frank Lawrence, Minneapolis-Honeywell Regulator Co., 2400 Wilkinson Blvd., Charlotte, N. C.
Second Friday, Cardinal Restaurant, Charlotte, N. C.

CENTRAL ILLINOIS
H. R. Getz, 723 Laura Ave., Peoria 5, Ill. Tel: 4-2800
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
Norman Krone, 123 N. Grant Ave., Indianapolis, Ind. Tel: IRvington 5337
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
H. G. Murray, 169 Durston Ave., Syracuse 6, N. Y. Tel: 9-9259
Third Monday, Dinner at 6:00 P. M., Meeting at 8:00 P. M.

CENTRAL OHIO VALLEY
J. C. Dilliner, 813 Winton Ave., Belpre, Ohio.

CHARLESTON
D. A. Cunningham, 5140 Washington Ave., S.E., Charleston, W. Va. Tel. 55403
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Airport Terminal Bldg.

CHICAGO
Floyd E. Ertsman, Rm. 1420, Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P.M., Hotel Shoreland.

CHINA LAKE
Beuhring W. Pike, 606-A Essex Circle, China Lake, Calif. Tel: 77782
Third Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS, Conference Room.

CINCINNATI
R. J. Eichner, 1900 Courtland Ave., Norwood 12, Ohio. Tel: Jefferson 3130
Second Monday, Dinner at 6:30 P.M., Meeting 8:00 P.M., Engineering Soc. of Cinn.

CLEVELAND
G. D. Carnegie, 3436 Lorain Ave., Cleveland.
Second Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, 2136 E. 19th St.

COLUMBUS
E. M. Chandler, 91 E. Como Ave., Columbus 2, Ohio. Tel: JE 9994.
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecelia St., Cumberland, Md. Tel: 583-W
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Alighan Shrine Country Club, Baltimore Pike.

DENVER
G. M. Peters, 3191 W. Denver Place, Denver 11, Colo. Tel: GRand 9073

DETROIT
Frank R. Davis, Edison Institute, Dearborn, Mich. Tel: LO 1-1620 Ext. 5517
Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.

EASTERN NEW YORK
Robert W. Carter, Sterling-Winthrop Research Institute, Rensselaer, N. Y. Tel. Albany 5-6251 Ext. 262
First Tuesday, Meeting at 8:00 P.M., Siena College, Loudonville, N. Y. Optional Dinner at 6:00 P.M., Circle Inn, Lathams, N. Y.
June 3, Subject: Instrumentation of Airline Aircraft. Speaker: M. G. Beard, Chief Eng., American Airlines.

GULF COAST
Harold Placette, 2440 Neches Ave., Port Arthur, Texas
Last Tuesday, Meeting at 7:30 P. M., Orange County Courthouse, Orange, Texas.

HOUSTON
A. Costa, 714 East 17th St., Houston 8, Texas.
Last Monday, Meeting at 8:00 P.M., University of Houston Library Building.

KANSAS CITY
J. C. Brous, 8827 Maiden Lane, Kansas City 5, Mo. Tel: HI 8556
First Tuesday, Meeting at 7:30 P.M., U. of Kansas City, Science Bldg., Rm. 106.

LOUISVILLE
C. M. Bosworth, 5336 Westhall Ave., Louisville, Kentucky. Tel: FR 3494
First Monday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
L. E. Henne, Bristol Co. of Canada Ltd., 712 Dominion Square Bldg., Montreal, Quebec, Canada Tel: UNiversity 6-4725.
Last Monday, 8:00 P.M., Mechanic's Institute.

NEW JERSEY
L. H. Ballinger, 2371 Channing Ave., Westfield, N. J. Tel: Westfield 2-0765M
First Tuesday. Meeting at 8:00 P.M., Essex House, Newark.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 520 South 14th St., New Hyde Park, N. Y. Tel: FI-7-0645.
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.

NIAGARA FRONTIER
Mrs. James L. Martin, 34 Manning Rd., Eggertsville 21, N. Y. Tel: WIndsor 0087
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
Bert L. Anderson, 1951 47th Ave., San Francisco 16, Calif. Tel: SEabright 1-5030
Third Monday, Dinner 6:30 P. M., Meeting 8:00 P.M., Spengers Grotto, 1919-4th St., Berkeley.

NORTHERN INDIANA
J. Baum Beckman, 7145 Wicker Ave., Hammond, Ind. Second Tuesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
George Ritscher, 113 Gorgas Lane, Oak Ridge, Tenn. Tel. 5-1084
First Wednesday, Meeting at 7:30 P.M., Ridge Recreation Hall
June 4, Demonstration and lecture on Use of Low Temperature Eutectic Welding Alloys for use in Instrument Design by the Eutectic Welding Alloys Corp.

ONTARIO
John W. Huether. 311 Southerland Dr., Leaside. Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
Bruno F. Loewen, Philips Chem. Co., Box 1526, Borger, Texas.
Third Tuesday, Meeting at 8:00 P.M.

PERMIAN BASIN
J. B. Jenkins, 509 South Ave. "C," Kermit, Texas. Tel: 3220
Second Tuesday, Meeting at 7:30 P. M., Gulf Oil Corp. Auditorium or Odessa College.

PHILADELPHIA
R. A. Trenner, Energy Control Co. Rm. 306, 3147 N. Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellevue-Stratford Hotel.

PITTSBURGH
W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa., Tel. Express 1-1330
Fourth Monday, Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.
May 26, A visit to the Aluminum Company of America Research Laboratory, New Kensington, Pa.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.
May 27, Subject: Instrumentation of Rocket Flight Testing. Speaker from General Electric Company.

RICHLAND
T. H. Quinn, 1513 Goethals Dr., Richland, Wash. Tel: 7-8717
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., Foxboro Co., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Hamilton 1468.
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
L. J. Hall, 730 Talfourd St., Sarnia, Ont., Canada. Tel: EDgewater 2258.
Second Monday, 8:00 P. M., Y.M.—Y.W.C.A.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

SOUTHERN MICHIGAN
Lyle J. Draper, 2233 Oakland Dr., Kalamazoo, Mich.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516.
First Wednesday After First Monday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.

TOLEDO
P. H. Girkins, 418 Waggoner Blvd., Toledo 12, Ohio. Tel: LA 6505
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
James L. Williams, 2237 Bruce St. Kingsport, Tenn. Tel: 2079-L
Fourth Thursday, Civic Auditorium.

TULSA
S. M. Bagwell, 1544 E. 35th Pl., Tulsa 5, Okla. Tel: 7-6822
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.

TWIN CITIES
Jerome J. Schwab, Engineering Sales, 516 Guardian Bldg., St. Paul 1, Minn. Tel: GArfield 0601
Fourth Tuesday, Dinner at 6:30 P.M., Meeting 7:30 P.M., Rm. 353, Coffman Memorial Union, U. of Minn.

WASHINGTON
Edward C. Lloyd, 2105 Spencer Road, Silver Spring, Md. Tel: SH. 9340.
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
J. R. McCauley, 18073 Archdale, Detroit 19, Mich. Tel: KE 1-5239.
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
E. Avery Taylor, Taylor Instrument Co., Industrial Trust Bldg., Rm. 510, Wilmington, Del. Tel: 9814.
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

First Corporate Member

The Executive Board at its regular meeting on March 27, 1952, voted unanimously in favor of recording Instruments Publishing Company as Corporate Member No. 1 of the Society.

LARGEST EXHIBIT

Continued from page 613

Ohmart Corp.
Palmer Thermometers, Inc.
Panellit, Inc.
Parker Appliance Co.
Penbethy Injector Co.
Perkin-Elmer Corp.
Permutit Co.
Photoswitch, Inc.
Physicists Research Co.
Potter Aeronautical Co.
Potter and Brumfield
Potter Instrument Co.
Production Instrument Co.
Proportioneers, Inc.
Pyrometer Instrument Co.
Research Control Co.
Robinson Aviation, Inc.
Rockwell Manufacturing Co.
R-S Products Corp.
Sanborn Co.
Sarco Co.
Scientific American Magazine
Servo Corporation of America
Sola Catalytic Co.
Sorenson & Co.
Southwestern Industrial Electronics Co.
Spence Engineering Co.
Standard Electric Time Co.
Herman H. Sticht Co.
Superior Electric Co.
Superior Tube Co.
Surprenant Manufacturing Co.
Swartwout Co.
Technical Sales Corp.
Telechron Department, GE
Telecomputing Corp.
Trans-Gel Products, Inc.
H. O. Trerice Co.
Trinity Equipment Corp.
Uehling Instrument Co.
U. S. Gage Div., American Machine & Metals, Inc.
Vapor Recovery Systems Co.
Veeder-Root, Inc.
Victoreen Instrument Co.
Vitro Corporation of America
Wallace & Tiernan Products, Inc.
Warwick Products Co.
Weatherhead Co.
Webber Appliances Co.
W. M. Welch Mfg. Co.
Wheelco Instruments Co.

A number of additional companies are in touch with the exhibit office. Among these newly interested companies the largest percentage are nuclear instrument manufacturers.

The attendance is expected to exceed 10,000. Hotel rooms will soon be at a premium. Members are, therefore, urged to make their room reservations as soon as they plan to attend the Conference and Exhibit.

The technical program is shaping up and a tentative program will probably be printed in the June issue of the *Journal*. In addition to the regular Instrument Maintenance Clinic, Dr. Axel Peterson has arranged an Analytical Instrument Clinic.

Cleveland Host Committee Chairmen Meet

The above picture was taken at a recent meeting of the Cleveland Host Committee Chairmen, held at the Engineering Society in Cleveland, Ohio. Back row, left to right: Gordon D. Carnegie, Milton M. McMillen, R. J. Carleton, Jr., Robert E. Tozier, George W. Gard, Richard E. Fritz, W. C. Uhl. Front row, left to right: Ed Baran, Fred Lennon, Robert Newton.

Cleveland Show Committee

Following are the members of the Host Committee for the Seventh National Instrument Conference and Exhibit, to be held in the Cleveland Auditorium, September 8-12, 1952:

Chairman: Fred A. Lennon

Vice-Chairman: Robert H. Newton

Entertainment Committee: A. E. Ehrke (Chairman), E. C. Baran, Francis Ely, Parker B. Howard, Robert H. Newton.

Employment Register Committee: Robert H. Newton, (Chairman).

Technical Advisory Committee: R. E. Tozier (Chairman), E. C. Baran, R. J. Carleton, A. J. Hilovsky, R. E. Pritz.

Maintenance Clinic Sub Committee: M. M. McMillen (Chairman), V. R. Bambeck, F. D. Cochran, Mandel Estrin, L. Hassell, R. H. Higgins, R. H. Joyce, J. C. Moise, L. G. Siegel, I. H. Strong, J. M. Tufft.

Ladies Welcoming Committee: Margaret J. Karns (Chairman). Mrs. E. C. Baran, Mrs. R. J. Carleton, Mrs. A. A. Hand, Mrs. F. A. Lennon, Mrs. L. G. Seigel.

Industries Day Committee: E. C. Baran (Chairman), Duanne R. Lamiman, Warren M. Wilson.

Cooperating Societies Sub Committee: A. J. McCullough (Chairman).

Publicity Committee: W. C. Uhl (Chairman), B. B. Farmer, G. A. Ollos.

Meeting Properties Committee: G. D. Carnegie (Chairman), John Flood, John Larimore.

Reception Committee: G. W. Card (Chairman), M. A. Blankenburg, H. R. Bowers, Clark H. Joy, F. W. Kirk, H. L Lee, H. W. Maurer, Jr., F. B. Miller, L. W. Sixt, R. J. Benson, H. A. Van Hala, R. E. Pritz.

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INSTRUMENT SALES REPRESENTATIVE. To sell complete line of industrial electronic test equipment. Exclusive basis. Location Ohio. Box 652.

SALES REPRESENTATIVE. To handle newly developed (Pat. Pend.) Thermocouple "Restorer"—revolutionary electrical device to be used in conjunction with existing pyrometers and controlling equipment. Helps assure proper temperature control despite poor, loose, oxidized connections or certain types of broken or deteriorated thermocouples. Sales Field includes Steel Producing and Steel Fabricating plants, also other industry using thermocouples and heat control. Excellent prospects for future. Offers one-time opportunity to obtain Sales District. Sales territories now being established. Applicants should have many years experience and contact with Heat Treatment and Instrument Men. All communications will be treated confidentially. Location Ohio. Box 653.

INSTRUMENT TECHNICIAN. Maintains and installs all types of recording, regulating, measuring and control instruments. Must be thoroughly experienced to work with minimum supervision from prints, sketches, and instructions in chemical plant producing caustic soda, chlorine, and chlorinated organic products. Rate $1.90 per hour to start and $2.15 per hour after six months. Liberal vacation, sick leave, and insurance plans. Location Memphis, Tennessee. Box 654.

SALES ENGINEER. Must be familiar with instruments and controls, both electrical and mechanical type, in public utility plant operation. Base salary and commission. Write experience, education, age, references, and salary required. Our employees know about this opening. Location New York City area. Box 655.

INDUSTRIAL INSTRUMENTATION. We have need of a few graduate engineers or physicists for permanent positions in Research and Development Department for work in long-range program of Instrument Design. Experience in instrumentation desirable. Salaries commensurate with training and experience. Location Philadelphia, Pa. Box 656.

GRADUATE ENGINEERS. Mechanical or Electrical Engineers, with several years instrument

Continued on page 627

Two New Sections Chartered

Following the recommendations of the Section and Membership Committee, the ISA Executive Board voted favorably on the Charter applications of two new Sections.

The Carolina Piedmont Section, located at Rock Hill, South Carolina, was granted an ISA Charter on January 18, 1952. Earl M. Seagrave, Jr., is President of this Section.

The Central Ohio Valley Section, located at Belpre, Ohio, was granted a Charter on March 27, 1952. Mr. J. C. Dilliner is Acting-Secretary and Treasurer of this group.

A great deal of active interest in forming new Sections in various parts of the country is becoming increasingly evident and should result in the formation of several more new Sections this year.

Resume of Thermocouple Checking Procedures

By HENRY C. QUIGLEY*

THE need for readily usable information concerning correct procedures for checking and calibrating various types of thermocouples has been indicated by numerous inquiries from plant personnel. It is evident that there is some confusion regarding factors affecting the accuracy of thermocouples. This paper is intended as a summary of methods, precautions, and limitations of thermocouple checking to serve as a guide for plant instrument personnel.

The quality of thermocouple wire being received from recognized distributors today has eliminated the need for routine calibration or checking of newly fabricated thermocouples, except in cases where extreme accuracy is required or calibration and quality are questioned. A second and important need for calibrating and checking thermocouples arises from the possibility of deviation from original calibration resulting from exposure to high temperatures, reactive atmospheres, and other detrimental conditions.

It was attempted to provide at least one good checking procedure for each accuracy range for the common types of thermocouples. In most cases, several equally applicable methods are given. Available equipment, frequency of need for such a procedure, personal skill and preference, and other such factors influence the final choice of method for each application.

The procedures given are of two general classifications: calibration by comparison with calibrated standards and calibration at fixed points. Under the former classification are presented the methods of comparison in place, in tube and muffle furnaces, and in baths. Under the latter, procedures utilizing freezing points, melting points, and boiling points are described.

FUNDAMENTALS

A basic understanding of the rules and precautions associated with the use and checking of thermocouples is essential if procedures for checking are to be fully understood and effectively conducted. Primarily, it must be realized that the emf produced by a pair of electrical conductors joined to form a thermocouple is not only dependent upon the difference in temperatures of the junctions, but also on the materials of which the conductors are constructed and the homogeneity** of all sections of conductor in regions of temperature gradient. If the emf of a thermocouple circuit is to be an accurate indication of the temperature being measured, the exact effect of these factors must be known.

REFERENCE AND MEASURING JUNCTION TEMPERATURES

Every junction between dissimilar metals in the thermocouple circuit other than the measuring junction must be held at a known temperature. Any number of different homogeneous metals may be inserted in the circuit between two points of equal temperature as long as all new dissimilar-metal junctions are at this same temperature. Usually a thermocouple circuit is designed so that there are only two significant junctions: the measuring or *hot* junction and the reference or *cold* junction. The emf of a homogeneous circuit is then related only to the difference in temperatures of these junctions.

The reference junction may be held at a constant known temperature by such means as an ice bath. Or the reference junction may consist simply of the connections to the instrument employed for emf measurement, in which case the temperature of these connections must be known. In some instruments, compensation for variations in this temperature is made by a secondary temperature-sensitive device.

If the two conductors leading to the instrument are of a third metal, not compensated to give the same emf-temperature relation as the measuring junction wires, then the reference junction temperature exists at the junctions of the third metal and the two measuring-junction metals.

Regardless of the nature of the reference junction, it must be kept in mind that the emf generated in any thermocouple circuit depends equally on the temperature of the reference and hot junctions, and the accuracy with which the hot junction temperature can be determined is thus limited by the accuracy with which the cold junction temperature is known or compensated.

COMPOSITION AND HOMOGENEITY

The composition of the thermocouple material at the junctions and in regions of temperature gradient determines the emf-temperature relation of the couple. Hence composition must be uniform and constant if reproducible results are to be obtained in temperature measurement. The most common materials and the temperature ranges in which they can normally be used are given in Table I.

The practical temperature range is somewhat lower for wires of small diameter. Couples for use at higher and lower temperatures than listed above have been developed, but methods for their checking are not included in this paper due to their limited use at present.

The Platinum-Rhodium thermocouple is of the rare-metal couple class characterized by high stability with the disadvantage of high initial cost and low emf output. In comparison, the base-metal couples, including the others listed above, are less expensive but also less stable. Of these, the Copper-Constantan couple is especially useful at low temperature since its emf-temperature relation is nearly linear in this range, although the emf produced is low, and materials of the exact composition are readily compounded.

The Iron-Constantan couple is recommended for reducing atmospheres, and the Chromel-Alumel for clean oxidizing atmospheres. Tables of the specific emf-temperature relations for each of these common types of thermocouples are published by the National Bureau of Standards and various instrument companies, but are applicable only to thermocouples which are of the exact composition for which the tables were developed.

VARIATION WITH MANUFACTURER

Although much has been done to standardize thermocouple compositions, couples of the same type but made by different manufacturers vary in emf-temperature relation enough in some cases to require different tables.

TABLE I

Type of Thermocouple	Wire Guage	Usual Temp. Range		Max. Temps	
Platinum-Rhodium	20	750 to 1038C	1300 to 1900F	1538C	2800F
Chromel-Alumel	14	315 to 815C	600 to 1500F	982C	1800F
Iron-Constantan	14	−18 to 550C	0 to 1020F	650C	1200F
Copper-Constantan	14	150 to 270C	−300 to 520F	343C	650F

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*E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Presented at the Sixth Annual Conference of the Instrument Society of America, Houston, Texas, Sept. 10-14, 1951.

**A homogeneous conductor is one in which the chemical composition and physical conditions are uniform throughout.

An example of this is the discrepancy between the iron-constantan tables published by the National Bureau of Standards (1938) and those of the larger companies which manufacture instruments using thermocouples, such as Leeds and Northrup, Tagliabue, Brown, and Bristol.

Thus, if a calibration table is not provided by the manufacturer, laboratory calibration of several representative couples will be required to establish the exact emf-temperature relation associated with a given lot or manufacture of thermocouple wire.

With continued use at elevated temperatures, thermocouples, especially base couples, become inhomogeneous due to oxidation, diffusion, distillation, corrosion and contamination. Much work has been done towards increasing the stability of thermocouples, both in selection of couple materials and in design of protection tubes. Rules have been formulated in an attempt to minimize the effects of inhomogeneity in regions of temperature gradient.

For example, the depth of immersion of a couple should never be reduced once it has been placed in service. Also, base couples which have been subjected to high temperatures (above 1000° F) should not be used for accurate measurement at lower temperatures. Despite all efforts, inhomogeneity cannot be prevented with any degree of certainty, and drift in calibration from the original emf-temperature relation specified for a given couple must be checked.

Procedures for Calibration and Checking

The most reliable methods of thermocouple calibration consist fundamentally of bringing the junctions of the couple to the same temperatures as those of a standard couple and comparing the emf's produced (Calibration by Comparison); or bringing the junction to known temperatures at which sample materials boil or freeze and measuring the emf of the circuit ("Fixed point" Calibration). Equipment for measuring emf is discussed later.

The accuracy of calibration at fixed points depends chiefly on the purity of the fixed-point samples; whereas, in calibration by comparison with a standard, the effectiveness depends on the accuracy of the standard and the extent to which the standard and test measuring elements can be brought to the same temperature.

In general, for the most accurate work, fixed-point calibration is more satisfactory than calibration by comparison because of greater certainty and straight-forwardness. The excessive time and attention required for most fixed-point procedures rule them out in cases where a quick calibration of moderate accuracy is desired. However, there are some relatively simple fixed-point procedures.

In checking thermocouples which are inhomogeneous, great care must be exercised to reproduce temperature gradients identical with those existing during normal service of the couples. Otherwise an accurate calibration is useless because of the difference in emf produced by an inhomogeneous section of wire when shifted from one temperature gradient to another.

Abrupt changes in emf-temperature relation due to inhomogeneity may be detected by connecting the two ends of the wire to a sensitive galvanometer and removing a source of heat, such as a Bunsen burner or small electric furnace, slowly along the wire. Gradual changes may be detected by doubling the wire and inserting it to various depths in a uniformly heated furnace, the two ends of the wire being connected to a galvanometer as before.

Calibration by Comparison

A standard temperature measuring device of known calibration and accuracy and a means of bringing this device to the same temperature as the test couple junction are the two requirements of effective thermocouple checking by comparison, assuming realization of the precautions outlined above. The method of bringing the measuring elements to the same temperature depends upon the accuracy desired in the check, the condition of the couple being tested, and other factors varying from one installation to the next.

The type of standard depends chiefly on the type of couple being checked and the accuracy desired. Plant economics is a factor that might affect the fulfillment of either of these requirements.

Calibrated Standards: Standard thermocouples are obtainable from various thermocouple suppliers, accompanied with certified calibration curves, at an extra charge of about $7.00 each. The National Bureau of Standards will calibrate and certify thermocouples for a fee of $7.00 each, also. Couples may be calibrated in the laboratory by methods described in this report and used as standards or sub-standards for comparison checking, if due consideration is given the accuracy obtained by the method used for standardization.

The use of resistance thermometers and liquid-in-glass thermometers as standards is sometimes practical. But best results are obtained when the standard is a thermocouple of the same type as the test couple. The practice in many plants is to have three Bureau of Standards couples on hand at all times. Two are held in reserve and the third is used to calibrate working standards.

At regular intervals, the third couple is compared with one of the reserve couples and if satisfactory agreement is not obtained, the two reserve couples are compared to make certain that there has been no drift in their calibration. Any practice which requires minimum use of the basic laboratory standard couples and provides a check on the accuracy of the standards will be sufficient.

Comparison in Place: Many authorities recommend checking all base couples in place (i.e., undisturbed in any way) since they are usually inhomogeneous after a short period of service. By this means, the problem of reproducing the exact temperature gradient along the couple wires is eliminated. Although the precision obtained using this method is not as high as is obtainable in the laboratory, the results are far more accurate in the sense of being representative of the behavior of the couples in service. Another advantage is the elimination of fatigue and crystal deformation by bending and handling which cause further inhomogeneity.

The specific procedure depends on the type of installation, but consists essentially of inserting the standard in the process area so that it attains as nearly as possible the same temperature as the test couple. A hole large enough to accommodate the standard couple may be drilled adjacent to the permanently installed couple. The standard couple is immersed in this hole to the same depth as the couple being tested, with the hot junction ends of the protection tubes as close together as possible.

In many installations there is a secondary protection tube into which the standard tube can be inserted alongside the questionable couple for comparison. Another less satisfactory method is the replacement of the test couple with the standard couple for a quick reading, before and after which a reading is taken on the test couple.

Although it may be felt that the checking of thermocouples in place is unsatisfactory due to the large variations in temperature from point to point throughout most processes, the reading of the standard couple represents the temperature of the fixed couple as closely as the temperature of the latter represents that of the process.

Comparison in the Laboratory: Thermocouples known to be relatively homogeneous, especially noble couples and couples which have not been used at high temperatures, can be calibrated more accurately in the laboratory than in place. A variety of laboratory procedures have been developed for bringing the junctions of test and standard couples to equal temperatures for calibration by comparison.

(1) *Tube furnace, junctions welded together*: For most accurate results, the junctions are spot-welded together and heated in an electric tube furnace.

A separate potentiometer and indicator are used for each emf and the emf's are compared continuously throughout the temperature range as the furnace heats and cools.

This procedure can be carried out using only one potentiometer if a double-pole double-throw switch with good contacts is employed for rapid alternate measurement of each emf during gradual temperature change. With any means of comparing emf's, consideration must be given the rate of temperature change in the furnace in determining the obtainable accuracy. The junctions are welded together easily and quickly by contacting them across the terminals of a welding current source.

(2) *Tube-furnace, junctions wrapped together*: Results nearly as good as those of the welded-junction procedure can be obtained by wrapping the junctions together with asbestos wire or metal foil. The procedures are otherwise identical.

(3) *Tube furnace, junctions differing greatly in size*: If the test couple junction is considerably larger than the standard junction, or vice-versa, a hole may be drilled in the larger junction so that the smaller junction may be inserted in it with minimum clearance for good thermal contact. The remainder of the welded-junction procedure is then followed.

(4) *Pipe and muffle furnace*: A fairly simple procedure requiring only readily available equipment consists of tying one or more test couples in a bundle with the standards in the middle and all other couples as close to it as possible. The bundle is inserted in a length of heavy pipe and placed in a muffle furnace. Accuracy depends on uniformity of temperature in the pipe and decreases with increase in number of couples in the bundle.

(5) *Drilled block*: An improvement over the pipe method is the use of a drilled metal block, preferably copper, having holes just large enough to accommodate the couples. The test holes are usually arranged in a circle around the standard couple hole. The block is held at various temperatures in a muffle furnace or a special electrical furnace designed specifically for this use. One such furnace and the drilled block for which it is designed are shown in Fig. 1.

(6) *Muffle furnace alone*: The use of a muffle furnace without any special means of providing temperature uniformity is often adequate for fairly accurate comparison, provided that no sharp temperature gradients exist. The current to the furnace is adjusted to the value which will ultimately give the temperature at which the comparison is to be made. The test and standard couples are placed in the center of the furnace where gradients are the mildest.

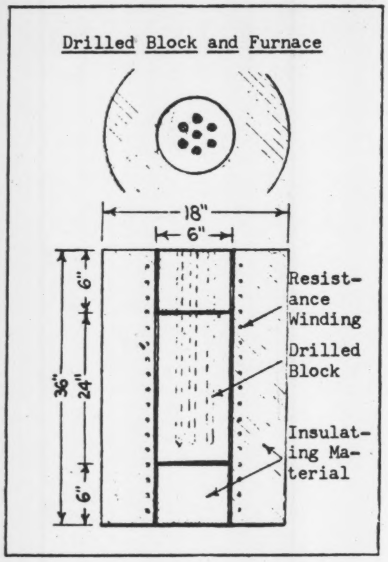


Fig. 1

The furnace temperature, as indicated by the standard couple, will gradually level off as equilibrium is approached. Readings should not be taken until the rate of change of temperature has decreased to the order of a degree per minute, or less — depending on the proximity of the couples and the time required to measure the emf's of all the couples at a given temperature, as well as the accuracy desired in the check.

(7) *Liquid Baths*: Liquid baths may be desirable for couple comparison in cases where it is necessary to check a large number of couples simultaneously or consecutively at the same temperatures, or undesirable to remove couples from their protecting tubes, or convenient to compare the couples with liquid-in-glass thermometers or other types of temperature measuring devices. Tin, melting at 232° C (450° F) and having a low volatility, makes a satisfactory bath liquid in the range 300 to 1000° C. Lead is also satisfactory. Oxidation of the bath material can be retarded by covering with a layer of powdered graphite.

Proper protection and immersion of the thermocouples is important. Usually the normal protecting tube is sufficient protection from contamination in metal baths. Positive protection with the disadvantage of increased insulation of the couple from the bath is obtained by using iron tubes large enough to accommodate the normal protection tubes, immersed close together to a depth of at least twelve inches, if possible. Of course, if the normal service temperature gradient conditions can be duplicated by less depth of immersion, so much the better.

The accuracy of the comparison is increased greatly by stirring the liquid continually during the comparison. Metal shields to protect the couples from direct radiation from the heating elements and baffles to control convection currents to the greatest advantage are refinements contributing to more accurate checking.

For low temperature work (below 500° C) elaborate bath facilities are common. Fig. 2 shows several typical test baths. The bath liquids most frequently used at lower temperatures are alcohol, water, oil and a eutectic mixture of sodium nitrate and potassium nitrate.

FIXED-POINT CALIBRATION

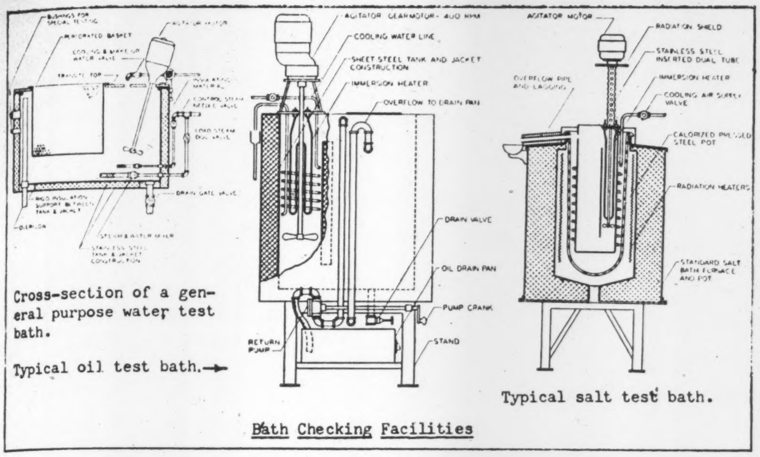
The maintenance of a known temperature for fixed-point calibration is accomplished by the use of a freezing or boiling point substance. The choice between freezing and boiling points is governed by the temperature desired, the apparatus available, and personal preference. In the determination of the emf of a couple at a freezing point, the time in which observations may be taken is limited to the period of freezing; whereas, in the boiling point method there is no such limit in time since the material can be boiled continuously.

In addition, there is sometimes a question as to the beginning and end of the interval of constant temperature characteristic of freezing. On the other hand, it is not necessary to observe the atmosphere pressure during freezing and, in general, simpler apparatus and less skill are required to obtain a given accuracy with freezing points.

The common boiling and freezing substances used in thermocouple calibration are given with the corresponding temperatures and equations for barometric pressure effect in Table II. The accuracy with which the actual thermocouple junction temperature approaches the theoretical fixed temperature of the chosen freezing or boiling substance depends on the purity of the substance and the exact nature of the apparatus. An accuracy of better than ±0.1° C is obtained by adding tap water to clean, shaven ice. The use of distilled water in a thoroughly cleaned container makes possible an accuracy of better than ±0.01° C.

The National Bureaus of Standards and various instrument companies provide standard freezing-point samples with certification of the freezing point of each lot. The purest materials are selected chiefly to provide the flattest possible freezing curves, the theoretical freezing points of the materials being of no importance as long as the actual freezing point of the particular sample is known. Of course, once the freezing point of a sample is established, great care must be exercised to avoid subsequent contamination of the sample, because an increase of 0.02 per cent impurity can change the freezing point as much as 0.1° C.

Calibration at Freezing Points: A typical apparatus for accurate freezing-point calibration is shown in Fig. 3. The procedure varies with the type of apparatus but consists basically of immersing the test couple and


BUSHINGS FOR SPECIAL TESTING
PERFORATED BASKET
COOLING & MAKE UP WATER VALVE
TRANSITE TOP
AGITATOR MOTOR
INSULATING MATERIAL
CONTROL STEAM REGULE VALVE
LOAD STEAM DUAL VALVE
DRAIN GATE VALVE
RIGID INSULATION SUPPORT BETWEEN TANK & JACKET
OVERFLOW
STEAM & WATER MIXER
STAINLESS STEEL TANK & JACKET CONSTRUCTION
AGITATOR GEARMOTOR - 400 RPM
COOLING WATER LINE
SHEET STEEL TANK AND JACKET CONSTRUCTION
IMMERSION HEATER
OVERFLOW TO DRAIN PAN
DRAIN VALVE
OIL DRAIN PAN
PUMP CRANK
STAND
RETURN PUMP
AGITATOR MOTOR
RADIATION SHIELD
STAINLESS STEEL INSERTED DUAL TUBE
OVERFLOW PIPE AND LAGGING
IMMERSION HEATER
COOLING AIR SUPPLY VALVE
CALORIZED PRESSED STEEL POT
RADIATION HEATERS
STANDARD SALT BATH FURNACE AND POT

Cross-section of a general purpose water test bath.

Typical oil test bath.→

Typical salt test bath.

Bath Checking Facilities

Fig. 2

protection tube slowly into the molten sample metal at 10° C above its freezing point; while cooling, the metal is stirred to assure uniform temperature throughout. The emf is noted at regular intervals of time.

These values are plotted and the emf corresponding to the flat portion of the resulting cooling curve is the emf at the freezing point of the metal. The number of couples which can be checked simultaneously is limited by the emf measuring facilities and time allowed for taking readings during the freezing period.

Freezing points are generally more accurately established than melting points when a large mass of the standard sample is employed, since an even heat distribution can be assured more readily in the former than in the latter. Also, the freezing point method facilitates control of immersion of the test couple, an especially important consideration in fixed-point calibration.

The couple must be immersed to a depth great enough to eliminate heating or cooling of the junction by heat flow along the wires and protection tube. A depth of five or ten times the diameter of the immersed assembly is usually sufficient. However, a simple check on proper immersion is obtained by noting any change in reading when the couple is shifted in or out a distance of several centimeters after equilibrium has been established. There should be no change.

Of course, this proper immersion is not related to the immersion necessary for duplication of the temperature gradient to which the couple is normally exposed. The accurate freezing and boiling procedures in this section are not usually utilized for the calibration of significantly inhomogeneous couples and hence duplication of temperature

TABLE II — FIXED POINTS AVAILABLE FOR CALIBRATING THERMOCOUPLES*

Thermometric fixed point	Values on the International Temperature Scale: Assigned (Primary points)		Determined (Secondary points)		Temperature of equilibrium (t_p) in ° C as a function of the pressure (p) between 680 and 780 mm of Hg.
	° C	° F	° C	° F	
Boiling point of oxygen	—182.97	—297.35			$t_p = t_{760} + 0.0126(p-760) - 0.0000065(p-760)^2$
Sublimation point of carbon dioxide			—78.5	—109.3	$t_p = t_{760} + 0.1443(t_p + 273.2)\log\frac{p}{760}$
Freezing point of mercury			—38.87	—37.97	
Melting point of ice	0.000	32.000			
Boiling point of water	100.000	212.000			$t_p = t_{760} + 0.367(p-760) - 0.000023(p-760)^2$
Boiling point of napthalene			217.96	424.33	$t_p = t_{760} + 0.208(t_p + 273.2)\log\frac{p}{760}$
Freezing point of tin[1]			231.9	449.4	
Boiling point of benzophenone			305.9	582.6	$t_p = t_{760} + 0.194(t_p + 273.2)\log\frac{p}{760}$
Freezing point of cadmium			320.9	609.6	
Freezing point of lead[1]			327.35	621.23	
Freezing point of zinc[1]			419.5	787.1	
Boiling point of sulfur	444.60	832.28			$t_p = t_{760} + 0.0909(p-760) - 0.000048(p-760)^2$
Freezing point of antimony			630.5	1166.9	
Freezing point of aluminum[1]			660.15	1220.27	
Freezing point of Cu-Ag eutectic alloy[2]			778.8	1433.8	
Freezing point of silver	960.5	1760.9			
Freezing point of gold	1063.0	1945.4			
Freezing point of copper[1]			1083.0	1981.4	
Melting point of palladium			1555.0	2831.0	
Melting point of platinum			1773.0	3223.0	

[1] **Standard samples of these materials are procurable from the National Bureau of Standards with certificates giving the freezing point of the particular lot of metal. The values given in this table for these materials apply for the standard samples that are being issued as of the present date.** [2] **28.1% copper and 71.9% silver by weight.**

***From "Temperature . . ." (3)**

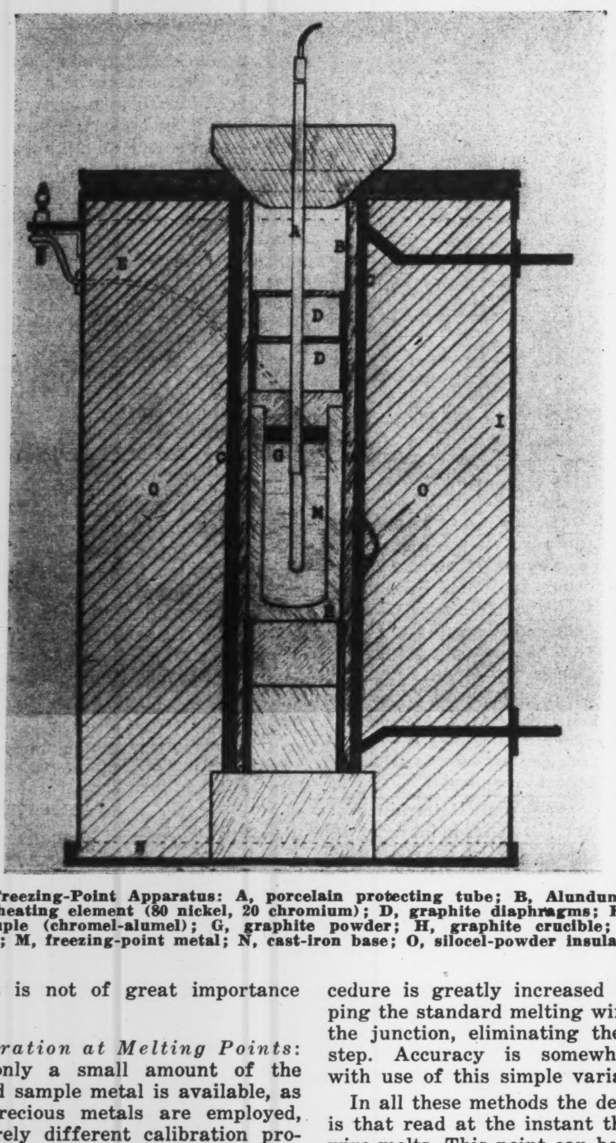


Fig. 3. Freezing-Point Apparatus: A, porcelain protecting tube; B, Alundum furnace tube; C, heating element (80 nickel, 20 chromium); D, graphite diaphragms; E, control thermocouple (chromel-alumel); G, graphite powder; H, graphite crucible; I, sheet steel; M, freezing-point metal; N, cast-iron base; O, silocel-powder insulation.

gradient is not of great importance here.

Calibration at Melting Points: When only a small amount of the standard sample metal is available, as when precious metals are employed, an entirely different calibration procedure is recommended. Certain variations of this procedure are also used quite extensively with common sample metals because of the extreme simplicity and speed obtainable without the sacrifice of much accuracy.

The procedure consists of spot-welding the thermocouple junction to the center of a two cm piece of standard sample metal in wire form (Fig. 4a). The temperature of this fabrication is raised slowly in a uniformly heated area of a furnace or other heating device until the sample melts. Good accuracy is obtainable.

A slightly greater accuracy, better than ±0.2° C., is obtained through an improvement of the method. The test junction is formed by welding each thermocouple wire to the sample wire at points one mm apart, (Fig. 4b). This method is especially valuable in checking thermocouple wire before fabrication of couples.

The convenience of the general procedure is greatly increased by wrapping the standard melting wire around the junction, eliminating the welding step. Accuracy is somewhat lower with use of this simple variation.

In all these methods the desired emf is that read at the instant the sample wire melts. This point can be observed visually or noted by the short interval of constant temperature and resulting constant emf during the period of melting, which may be only a fraction of a minute. If the melting point can not be detected by either of these methods, the second procedure above should be followed and the emf noted at its highest value before the circuit breaks.

Calibration at Boiling Points: The steam point is the most common boiling point utilized in fixed-point calibration. A beaker of boiling water provides a fixed temperature of 100± 1° C. An accuracy of ±0.01° C can be realized in an apparatus of the type shown in Fig. 5. In this device, the vapor-tension point is established by boiling the substance under an "umbrella" and radiation shield. Appropriate equations for relating boiling points to prevailing atmospheric pressure are to be found in Table II.

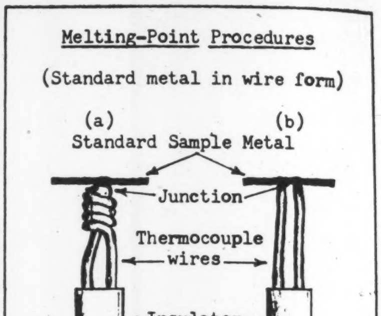


Fig. 4a **Fig. 4b**

Among others, sulfur, benzophenone, Dowtherm and naphthalene boiling points can be maintained in such apparatus. However, these points are near freezing points of available metals of high purity and are seldom used in the calibration of thermocouples.

Low Temperature Calibration: Solid carbon dioxide, usually readily available, provides a convenient calibration point for the range 0 to -90° C. However, the exact sublimation temperature of -78.51° C is not realized unless the atmosphere above the "dry ice" is pure carbon dioxide. This temperature can be held winth 1° C by adding carbon dioxide snow to a low-freezing liquid such as acetone or kerosene in a wide-bottom, narrow-mouth vessel, the copious initial evolution of carbon dioxide assuring adequate displacement of diluent gases. The test couple is immersed in the resulting slush and readings are taken when the emf of the couple approaches a constant value despite the addition of more carbon dioxide snow.

An accuracy in the neighborhood of 0.01° C can be realized for the carbon dioxide point by burying an electrical heating coil near the bottom of a Dewar flask of dry ice and placing the test couple about five cm above it. To bring the dry ice to equilibrium with its vapor, 25 or 30 watts are delivered to the heater. In ten of fifteen minutes a constant temperature will be reached, and 6 or 7 watts will be sufficient to provide a steady evolution of gas for the purpose of preventing air from diffusing into the flask. The effect of a barometric pressure is accounted for in the appropriate equation of Table II.

The range of calibration may be extended to -190° C by utilization of the *oxygen boiling point*, -182.97° C, in addition to the sublimation point, procedure is really one of comparison. Liquid oxygen, at its boiling point, is stirred in a Dewar flask. The test couple and an oxygen vapor-pressure thermometer are immersed in the bath and their readings compared.

An oxygen vapor pressure thermometer is simply a glass tube containing very pure oxygen at a pressure of several atmospheres at room temperature, and connected to a mercury-filled manometer for measuring the pressure in the tube. When the thermometer is immersed in the bath, part of the oxygen liquefies. The temperatures of the bath is related to the pressure in the thermometer by the equation given in Table 2 for oxygen.

INTERPOLATION BETWEEN CALIBRATION POINTS

The number of points at which a thermocouple is checked is a question of considerable importance. The uncertainty of readings between calibrated points increases proportionally with reduction of the number of points. The intermediate values may be determined by use of an empirical equation satisfying the conditions at all of the calibration points, or by drawing a smooth curve through the plotted points, or by linear interpolation between points, depending on the accuracy desired for interpolated values. A common practice for accurate calibration is a combination of these means, the employment of a difference curve and a simple empirical equation, the curve showing deviation from the equation.

In cases where emf varies nearly linearly with temperature in the range used and where high accuracy isn't essential, one or two calibration points may be sufficient for establishing or checking the calibration of a couple. In the range 0 to 1500° C, a curve for interpolation to 1 or 2° C usually requires points not more than 200° C apart.

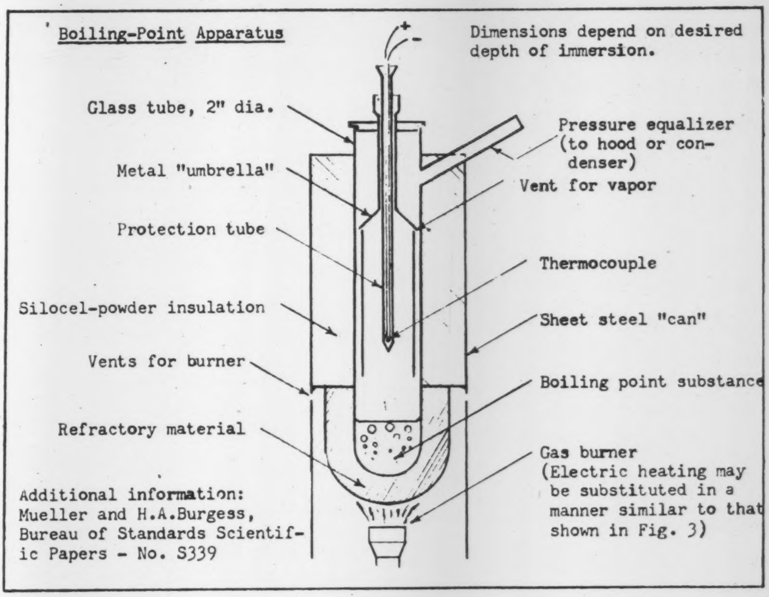

Boiling-Point Apparatus
+
-
Dimensions depend on desired depth of immersion.
Glass tube, 2" dia.
Pressure equalizer (to hood or condenser)
Metal "umbrella"
Vent for vapor
Protection tube
Thermocouple
Silocel-powder insulation
Sheet steel "can"
Vents for burner
Boiling point substance
Refractory material
Gas burner (Electric heating may be substituted in a manner similar to that shown in Fig. 3)
Additional information: Mueller and H.A.Burgess, Bureau of Standards Scientific Papers - No. S339

Fig. 5

The uncertainty of interpolated points can be reduced by plotting a difference curve of the deviation of calibration values from corresponding reference table values for that particular type of couple. Such emf-temperature tables are found in most instrument company catalogs and National Bureau of Standards thermocouple publications, as mentioned earlier.

FREQUENCY OF CHECKING AND REPLACEMENTS

The frequency with which thermocouples should be checked depends so much on the conditions under which they are used that few generalizations can be made. Under constant specific conditions, however, couples depreciate at a somewhat predictable rate, and

TABLE III — RECOMMENDED PROCEDURES FOR THERMOCOUPLE CALIBRATION

Required Accuracy:	±0.1 to 0.2°C		±0.5 to 1.0°C				±2.0 to 4.0°C			
Temperature Range:	Low	High	Low		High		Low		High	
Type of Couple:	Both	Both	Base	Noble	Base	Noble	Base	Noble	Base	Noble
Procedures: (See text under "Procedures for Calibration and Checking")										
Calibration by Comparison:										
In place:			D		D		A		C	
In laboratory:										
(1)	B	A				A				
(2)	A		A	A	A	B			B	B
(3)	B	B								
See corresponding number in text for description.										
(4)			C	C	D	D	B	B	B	B
(5)	D	D	B	B	C	C	B	B	A	A
(6)			D		D		A	A	B	C
(7)	A		B	B			B	B		
Fixed-Point Calibration:										
At freezing point-	D	D	A	A	B	B				
At melting points-	B	B	B	B	B	B	B	B	B	B
At boiling points-	B		B	B			B	B		
Low temp. Sub-zero range										

*Refer to procedures for limiting conditions

Key: A - Preferred Procedure. B - Usable, preferred in some cases. C - Adequate for minimum prescribed accuracy. D - Usable only with most favorable conditions.

hence their useful life can be estimated from previous experience.

In fact, many companies follow the practice of replacing their couples on regular schedules without any checking. This practice is economical for inexpensive base metal couples, since checking often costs more than replacement and the calibration of new couples and thermocouple material is customarily certified by the manufacturer at the time of purchase.

The replacement schedule should allow sufficient safety margin so couples are always well within the required accuracy limits despite moderate irregularities in process conditions which might enhance deterioration. This schedule should be developed from experience with couples in the specific application under consideration, and will vary considerably from one application to the next. A couple used in a harmless atmosphere at low temperatures may have a useful life of a year or more; whereas, a couple exposed to harsh conditions, especially high temperatures and oxidizing atmospheres, may be good for only a 100 hours or so.

Couples used as plant or laboratory standards should be checked or discarded with a frequency consistent with the accuracy expected from them, with consideration for the temperature ranges in which they are used. For example, a standard base-metal couple used above 1000°F for the most accurate work should be discarded after a maximum of ten hours' use.

In determining the frequency of checking or schedule of replacement of service or standard couples, it must be kept in mind that no two cases are identical and careful consideration should be given the type of couple, length of continuous service, average and extreme conditions to which exposed, type of protection, quality of materials, record of similar couples used in comparable environments, and all other factors affecting or revealing homogeneity and calibration.

Instruments for Measuring Emf

Several instrument companies provide a number of instruments recommended specifically for thermocouple calibration. Portable potentiometers with reference junction compensators are available for noble-metal couples or base-metal couples or both. Most of these instruments are quite suitable for all in-place checking procedures. Several portable potentiometers on the market are adequate for plant or laboratory tests within an accuracy 0.5° C and are ideal for general calibration and checking.

For laboratory procedures requiring the highest accuracy, various laboratory potentiometers with special refinements are available. The galvanometer-type of millivoltmeter is unsatisfactory for all except the roughest work due to the error introduced by the resistance of the thermocouple circuit and variations in ambient conditions.

As the accuracy of the potentiometer is as important as the accuracy of the couple in thermocouple checking, the same is true in the normal service of thermocouple systems. Hence, it is recommended that the regular pyrometer of the circuit be checked as well as the thermocouples it serves.

Summarization of Calibration Procedures

Table III summarizes the recommended checking procedures for various degrees of accuracy and temperature ranges. This table is meant only as a guide, and should not be used without reference to all pertinent limitations and precautions discussed above.

BIBLIOGRAPHY

Part of the information used in the compilation of this report was obtained from Du Pont experience and manufacturers' catalogs. The remainder was obtained largely from the following references:

1. Farrar, G. L., and Platt, A. M., *The Petroleum Engineer,* 21, 13, C5-C10 (1949).

2. Foote, P. D., Fairchild, C. O., and Harrison, T. R., "Pyrometric Practice" (Tech. Paper, NBS, No. 170), Washington, D. C., Government Printing Office, 1921.

3. "Temperature, Its measurement and Control In Science and Industry," New York, N. Y., Reinhold Publishing Corp., 1941.

The latter is a very complete reference book on all aspects of the use and maintenance of thermocouples as well as other types of temperature measuring devices, comprising the papers presented at a symposium on the subject conducted in 1939 by the American Institute of Physics, the National Bureau of Standards, and the National Research Council. This book would be a valuable addition to the plant or instrument group library.

An Improved Luft-Type Infrared Gas and Liquid Analyzer

By JAMES L. WATERS* and NELSON W. HARTZ**

THE developments covered herein are in the field of continuous infrared analyzers for industrial use. Before these developments are discussed, the two classes of infrared analyzers and their applications to analytical problems will be considered.

The infrared absorption of a compound is a characteristic of the type and arrangement of the atoms composing the molecule. The frequency or wave length at which absorption occurs is determined by the mass of the atoms and the strength of the bond joining them. This is analogous to the resonance of a spring-supported weight, in which the natural frequency is determined by the spring constant and the mass of the weight.

It has been found experimentally that dissimilar compounds absorb in widely different spectral regions. For instance, carbon monoxide, water vapor, ammonia, methane and sulphur dioxide differ greatly in their absorption patterns. On the other hand, similar compounds have similar spectra. The absorption of ethane, propane and butane is quite similar although there are regions of absorption difference. Fortunately, these differences are sufficiently marked so that it is possible to determine a small percentage of one of these gases in the presence of a much higher concentration of the other two.

Because compounds have characteristic absorption, it is possible to analyze a vast variety of mixtures with one basic type of analyzer. This is probably the greatest single advantage of the infrared method.

The theory of the absorption characteristics of molecules have been developed since 1800. The knowledge in this field has gradually increased throughout the years and is due to the work of many investigators. Among these are such men as Tyndali, Langley, Coblentz, and Pfund.

Two Types of Analyzers

Two classes of infrared analyzers have been developed for the investigation and application of infrared radiation. The first of these, the spectrometer, was first developed as an aid to the discovery of facts about infrared radiation. It has also found general use in the analysis of chemical mixtures. A spectrometer in its simplest form consists of an infrared light source, a sample cell, a light dispersing system and an infrared detector.

The absorption of the sample material is determined at each wave length or frequency of infrared light. From this data sample transmission can be plotted as a function of wave length. Modern spectrometers automatically plot the spectra of a compound in less than 15 minutes. From the absorption spectra of a mixture, the spectroscopist can calculate the composition of the mixture.

The non-dispersion instrument is the second type of infrared analyzer. It consists of an infrared source, a sample and filter cell, and an infrared detector. Since the light is not dispersed, this analyzer makes a simple measurement of the absorption by the sample

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in those spectral regions which normally reach the detector and cause an output signal.

When suitable detectors, windows, sources, and filters are used, the non-dispersion analyzer can be made extremely selective to one compound. This is true even in samples in which the components are very similar.

Experience has shown that the spectrometer and the non-dispersion analyzers are complementary. Each has its place. The spectrometer is ideally suited to laboratory and pilot plant use where it is necessary to analyze many different types of mixtures for many different compounds.

The non-dispersion instruments are primarily used for industrial process control where an analysis for one component of a mixture is desired. Although the non-dispersion instrument can be used on many different analysis problems, the sensitizing and calibration of such an analyzer for a different problem generally requires considerable time and effort.

DESCRIPTION OF NON-DISPERSION TYPE

The non-dispersion analyzers are classed in two categories. These are the *selective* and the *non-selective* detector types which have also been termed, respectively, the *positive* and *negative filter* instruments. The authors feel that the names selective and non-selective detector instruments are self-defining and, therefore, to be preferred. For this reason these terms are used in the rest of this paper.

A schematic diagram of a non-selective detector instrument as originally proposed by Schmick is illustrated in Fig. 1. In this system light from two sources, S_1 and S_2, is directed to two detectors, D_1 and D_2, which are usually bolometers or thermopiles. The detectors are electrically connected in opposition so that they measure the difference in light intensity between the two beams.

Assume cells X, Y, and F are filled with non-absorbing gases. When an absorbing gas enters the sample cell through which both beams pass, the gas reduces the radiation in each beam by a similar amount. As a result, no difference between the beams is produced and the detectors have no output. In other words, the analyzer is not sensitive to absorbing gases.

SENSITIZING NON-SELECTIVE SYSTEM

In order to sensitize the non-selective detector system the following method is usually employed. Assume a hypothetical mixture of absorbing gases A and B and a non-absorbing gas is to be analyzed. Cell X is filled with A, the gas to be detected. Cell Y is filled with a non-absorbing gas.

The gas A in the sample cell, passing through both beams, will affect the Y beam more than it affects the X beam because the A gas in X has already removed most of the spectral regions at which A absorbs. Thus the beams will be unbalanced and an output signal will be generated by the two detectors. When the analyzer is calibrated in this manner it will also be sensitive to gases which have overlapping bands with A.

If B has bands that overlap A, gas B will be placed in the filter cell F so that it removes most of the energy in the bands absorbed by B. This reduces the sensitivity of the analyzer to B, and hence increases the selectivity of the analyzer to A.

In some cases the techniques mentioned in the previous paragraphs are not sufficient to obtain the desired selectivity. During the past five years several independent investigators have developed a method for obtaining higher selectivity. This method requires that cell Y, instead of being filled with a non-absorbing gas, be filled with a mixture of B and a non-absorber.

The concentration of B is adjusted so that when B is placed in the sample cell it affects the two beams equally and thus produces no output signal. When A is introduced into the sample cell, it affects the Y beam more than it affects the X beam and thus causes an output. Since the sensitivity to B is virtually zero and there is still sensitivity to A, the selectivity of the analyzer has been greatly increased.

SELECTIVE DETECTOR SYSTEM

The second type of non-dispersion analyzer is the selective detector instrument. A schematic diagram of this type of analyzer as developed by Luft is illustrated in Fig. 2. The light from two sources, S_1 and S_2, is directed into two detector chambers, D_1 and D_2. The selective differs from the non-selective instrument in the type of detector used.

One type of selective detector is a volume of infrared absorbing gas. When radiation is absorbed by the gas, the temperature and pressure of the gas increase. This pressure increase is generally measured with a condenser microphone.

Only those spectral regions which are absorbed cause a pressure increase and hence the detector is selective to the regions which are absorbed.

In the Luft analyzer the two detectors, D_1 and D_2, are separated by a membrane so that the only time the membrane is deflected is when one beam is stronger than the other. In this way the output of the condenser microphone is a measure of the difference in intensity between the two beams.

With the same hypothetical problem involving the absorbing gases A and B and a non-absorbing gas, the selective detector instrument would be sensitized in the following manner. Gas A would be placed in the detector chambers D_1 and D_2. When gas A is passed through the sample cell, it reduces the intensity of the sample beam. This produces an output signal.

Since the detector is filled with A, it is sensitive only in those spectral regions absorbed by A. Thus, only gases which have overlapping bands will affect the measurement. If B has interfering bands, it is placed in cell F so that the wave lengths absorbed by it are removed before the light enters the detector.

COMPARISON OF SELECTIVE TYPES

Two types of selective detector analyzers have been described in the literature. In 1939 Pfund proposed a selective detector instrument. This was a single beam system consisting of a source, a sample cell and a detector. If carbon dioxide in air were to be measured, carbon dioxide would be placed in the detector. First, a sample of air and then a sample of CO_2 free air would be passed through the sample cell. Thus, the difference between the output of the detector in the two cases is a measure of the gas concentration.

About the same time in Germany, Luft of the I. G. Farben Industries developed the selective system previously discussed. The Luft system had distinctive features as compared with the earlier non-selective systems. These

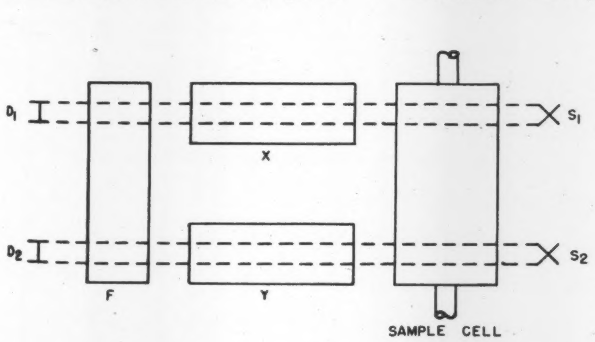


Fig. 1

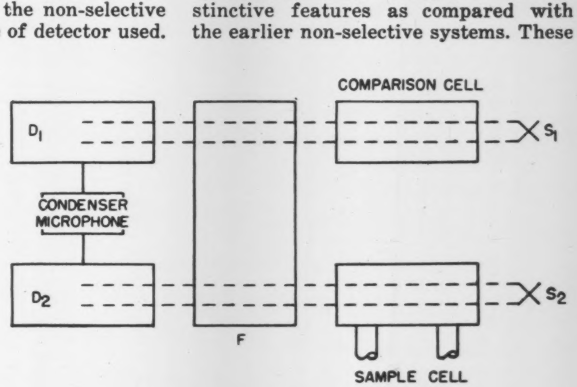


Fig. 2

features are a selective detector and interrupted radiation.

In order to understand the features of a selective detector, assume that carbon monoxide is to be analyzed for. The detector is then selectively sensitized by filling with carbon monoxide. When so sensitized, between 60 and 90 per cent of all the radiation affecting the detector is in the spectral regions which are absorbed by carbon monoxide. Hence, carbon monoxide in the sample cell absorbs a very high percentage of the effective radiation.

By comparison, when a non-selective detector is used under similar conditions, only a small fraction of the total effective radiation is absorbed by carbon monoxide in the sample cell. Thus, the selective detector instrument measures a larger component, and is less subject to analysis errors due to changes in the optical paths of the instrument.

ADVANTAGE OF INTERRUPTED RADIATION

The use of interrupted radiation as developed by Luft yields several advantages. In the Luft analyzer both beams are blocked simultaneously and then passed, and the amplifier is tuned so that only signals varying at the frequency of interruption are amplified. Since the amplifier responds only to the interrupting frequency, ambient temperature gradients do not cause errors because the change in gradient is much slower than the interrupting frequency.

Now compare this with the continuous radiation instruments which measure very small differential temperatures between their detectors. In this type of instrument ambient temperature gradients across the detectors cause serious errors unless close thermostating is employed. The drift due to ambient temperature changes usually limits the stability and sensitivity of this type of instrument.

Although the Luft-type analyzer has advantages, it is not an entirely satisfactory instrument. The original analyzer built by Luft was sensitive to vibration when operated at high sensitivity. In addition span and zero drifts of several per cent in a day were commonly encountered. In spite of these limitations several hundred analyzers were manufactured by the I. G. Farben Industries during the last war for use in German chemical plants.

The authors believe that the Luft instrument is basically a very desirable infrared analyzer. In order to overcome the undesirable features of the original instrument the MSA Infrared Gas and Liquid Analyzer (LIRA type) has been developed. LIRA stands for Luft-type Infrared Analyzer.

DESCRIPTION OF LIRA

LIRA is shown schematically in Fig. 3. Two similar nichrome filaments are used as sources of infrared radiation. Beams from these filaments travel through parallel stainless steel cells. One beam traverses the *sample cell* and the other the *comparison cell*. The emergent radiation is converged into the single detector cell by a *beam combiner* which consists of two cylinders in the form of a V.

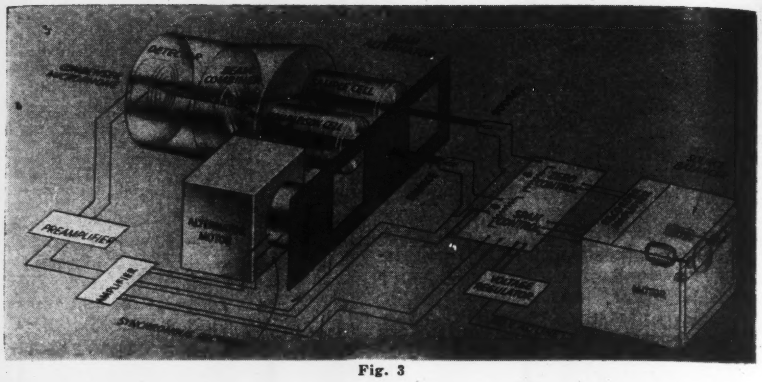


Fig. 3

As the gas in the detector absorbs radiation its temperature and pressure increase. An expansion of the detector gas causes a condenser microphone membrane to move. This movement, when converted and electrically amplified, produces an output signal.

Between the source and the cells, a reciprocating metal slider alternately blocks the radiation to the sample cell and to the comparison cell. When the beams are equal, an equal amount of radiation enters the detector from each beam. The amplifier is tuned so that only variations in light intensity occurring at the alternating frequency produce an output signal. Therefore, the beams are equal and the output is zero.

When the gas to be analyzed is introduced into the sample cell, it absorbs and thus reduces the radiation reaching the detector from the sample beam. As a result the beams become unequal and the radiation entering the detector flickers as the beams are alternated. The detector gas expands and contracts in accordance with the flicker. In this way, the detector directly indicates the difference between the two beams.

The expansion and contraction of the gas causes the membrane to move in response. The membrane movement varies the condenser microphone capacity. The variation in capacity generates an electrical signal which is proportional to the difference between the two radiation beams.

Next, the electrical signal is amplified by a conventional a-c amplifier and then conducted to a synchronous rectifier. The synchronous rectifier generates a d-c signal, the polarity of which depends upon which of the two beams is stronger. This d-c signal, which is due to an increase in sample absorption, causes an electronic recorder to drive upscale. As the recorder drives upscale, it causes a reduction in the voltage applied to the comparison beam source.

The recorder continues to drive upscale until the beams are returned to balance. The position of the recorder indicator is then a measure of the absorption of the sample and hence the concentration of the analysis component. Thus, the recorder automatically and continuously provides a record of the composition of the sample mixture.

IMPROVEMENTS OVER ORIGINAL LUFT-TYPE ANALYZER

LIRA possesses the desirable properties of the Luft-type analyzer (a selective detector and interrupted radiation) and it overcomes some of the difficulties encountered with the original Luft analyzers through the use of a beam alternator and a null balance system.

In the Luft analyzer the beams were directed into two detector chambers connected in opposition but separated by the membrane of a condenser microphone. With this arrangement, the sensitivity of the detector in one beam could change with respect to the sensitivity in the other beam. As an example, leakage of the gas from one side of the detector would cause a drift in the zero of the instrument.

LIRA alternately receives the two beams in a single detector chamber. There is no possibility of the detector for one beam changing with respect to the detector for the other beam. This modification reduces zero drift and contributes to increased stability.

In the original Luft-type instrument

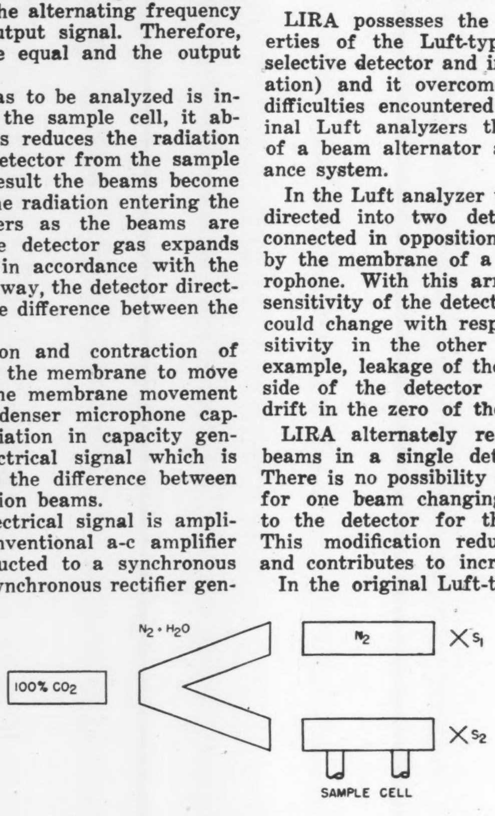


Fig. 4

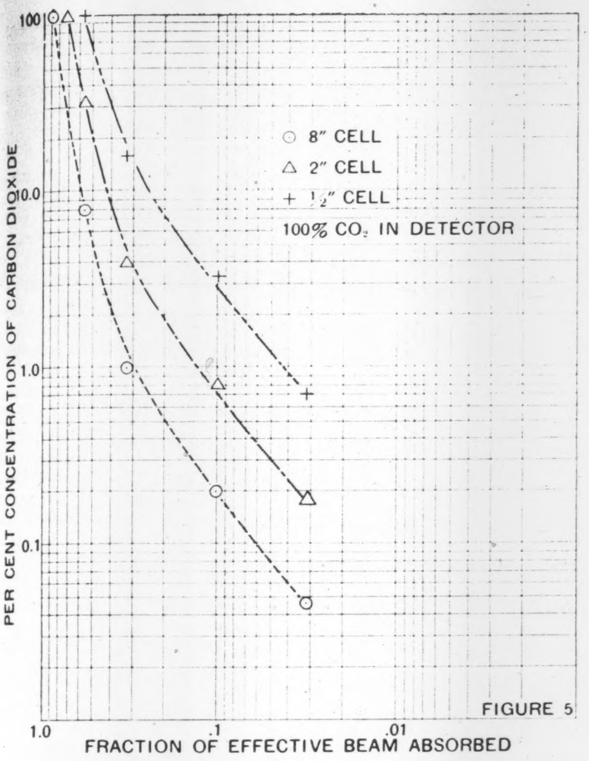


Fig. 5

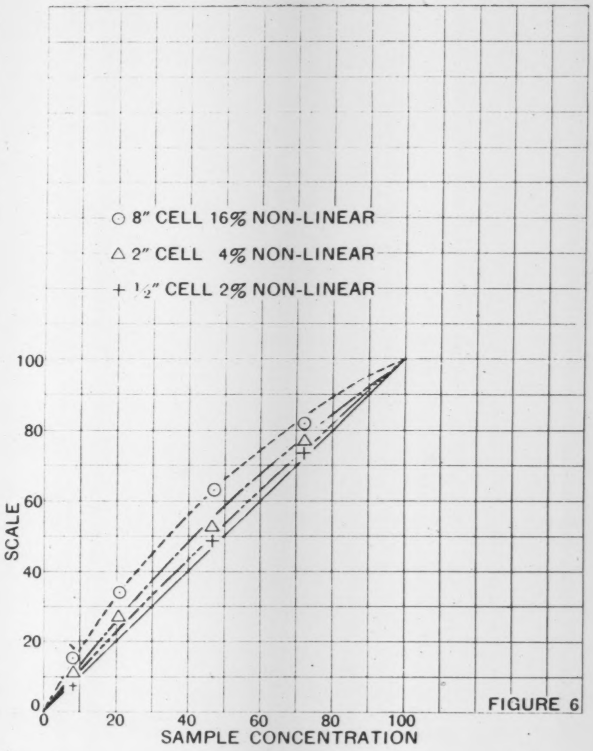


Fig. 6

the magnitude of the signal output of the amplifier caused by the optical unbalance is used to measure the sample concentration. Any change in gain of the detector amplifier system caused by ambient temperature changes or aging of the components results in a change in span of the analyzer.

LIRA uses a null balance system. The position of the null is not dependent upon the gain of the amplifier or detector. As a result, a high stability in the span of the analyzer is obtained.

PRACTICAL APPLICATION CONSIDERED

So far we have discussed infrared analyzers in broad, general terms. We will now discuss the actual operation characteristics of LIRA and mention several analysis problems which can be solved with this instrument.

The problems to which LIRA has been applied fall into two classes, namely: those involving gaseous mixtures and those involving liquid mixtures.

When gas streams are analyzed, the sample cell length, the window materials, and the concentration of the gas in the detector are determined by the composition of the sample stream. The effect of these factors can be illustrated by a discussion of several actual problems.

The problem of measuring zero to one per cent carbon dioxide in air is relatively straightforward. The components of this mixture are about two per cent water vapor, traces of other absorbing gases and the balance are non-absorbing gases such as nitrogen and oxygen.

As shown in Fig. 4, LIRA when calibrated for this problem would use a sample cell about two inches long and a concentration of 100 per cent carbon dioxide in the detector. Since nitrogen and oxygen are non-absorbing gases, they will not produce error signals. On the other hand, water vapor is an absorbing compound and its effect on the analysis must be determined.

The absorption bands of water vapor are many but they are not as strong as that of carbon dioxide. In addition, few of the absorption regions of water are common with those of carbon dioxide. With an analyzer for zero to one per cent carbon dioxide, the error signal from two percent water vapor can be made equivalent to less than 0.005 per cent carbon dioxide. It can be seen that a selective analysis for zero to one per cent CO_2 in air is readily obtained.

DETERMINING SAMPLE CELL LENGTH

A sample cell length of two inches for the analysis of this particular mixture was chosen with good reason. Fig. 5 shows the relationship between carbon dioxide concentration in air and the absorption in the sample cell. Curve 1 is for a ½-inch cell; Curve 2 for a two-inch cell and Curve 3 for an eight-inch cell. The 1 per cent CO_2 in an eight-inch cell absorbs 35 per cent of the total radiation; in the two-inch cell, 13 per cent and in the ½-inch cell, 5 per cent.

Thus, strictly on the basis of signal output, the eight-inch cell would be most desirable. The linearity of absorption as a function of concentration is also important because this affects the linearity of the calibration of the analyzer. Fig. 6 shows a plot of absorption versus concentration for CO_2 between 0 and 1 per cent. It will be noted that the curve for the eigth-inch cell is 16 per cent non-linear; the two-inch cell is 4 per cent non-linear; and the ½-inch cell, 2 per cent non-linear.

From this data it can be seen that the choice of a two-inch cell is rather arbitrary. It is a compromise between linearity and signal output effect. If very high linearity is desired, a ½-inch cell can be used.

This illustrates the importance of using a cell length which is suited to the analysis problem. In each analysis the cell length best suited to the probem is used. LIRA is available with gas cells in standard lengths between 0.1 and 20 inches.

A linear calibration for an analysis instrument greatly increases its usefulness. Linearity is dependent upon two factors, namely: the linearity of absorption versus concentration, and the analyzer linearity of output versus absorption. LIRA is instrumentally linear to within a few per cent. It has been experimentally determined that non-linearity is less than five per cent in the majority of the gas analysis problems encountered to date.

MEASURING LOW CONCENTRATIONS

So far, an easy problem has been described and several factors which govern the application of LIRA have been explained. Problems become more difficult in two ways. The solution of very low concentration or very high selectivity problems can be required.

A low concentration problem would be an analysis in the range 0 to 200 parts per million of carbon monoxide in air. For this analysis it is desirable to use a cell 20 inches long. Nonlinearity can be neglected because it does not become appreciable until cell lengths of 40 inches or longer are used.

The physical size of analyzers with cells longer than 20 inches is rather cumbersome; as a result, 20-inch cells are the longest generally used. The composition of the mixture is 200 ppm carbon monoxide, about 300 ppm carbon dioxide, two per cent water vapor and the rest non-absorbers or present only in traces. This type of analyzer is sensitized with a mixture of carbon monoxide in dry nitrogen in the detector.

Fig. 7 shows the gases with which the cells are filled.

The filter cell is filled with carbon dioxide saturated with water vapor. In this way the effects due to carbon dioxide and water vapor are reduced to a minimum. The concentration of 300 ppm carbon dioxide gives a false deflection equivalent to less than 2 ppm of carbon monoxide. However, the two per cent water vapor gives a false deflection equivalent to 70 ppm of carbon monoxide. The error due to water vapor is considerable and must be reduced.

There are two methods of reducing this effect. One is to dry the sample stream. The second is to reduce the cross-sensitivity. Techniques are at present being developed for reducing this cross-sensitivity factor. To date it has been reduced so that two per cent water vapor gives a false deflection equivalent to only 20 ppm carbon monoxide. The objective is to make it appear as less than 2 ppm carbon monoxide.

SELECTION OF GAS IN DETECTOR

Referring back to Fig 7, note that the detector is filled with a mixture of carbon monoxide in a non-absorber instead of being filled with pure carbon monoxide. When a high concentration of sensitizing gas is placed in the detector, the radiation in the very strongest bonds is absorbed very close to the windows. When this happens the heat is localized in the gas near the window and is conducted away. Hence, it does not cause as much expansion as it would if the absorption occured throughout the body of gas.

This means that the detector is less sensitive to the strongest absorption regions than it is to weaker regions. To overcome this disadvantage, the concentration of the absorbing detector gas is reduced by diluting with a non-absorbing gas. Obviously, if this is carried too far, the sensitivity drops because there is not enough absorption in the detector. The proper concentration of detector gas is determined experimentally. This adjustment of detector gas concentration becomes most important when the highest possible sensitivity is desired.

The maximum sensitivity that can be obtained is limited by the noise level of the detector system and the vibration level encountered at the installation site.

For problems with spans between 0 to 0.5 per cent and 0 to 100 per cent the noise level and vibration effects do not cause errors in the measurement. However, when spans from 0 to 0.5 per cent down to 0 to 0.01 per cent are attempted, these factors must be considered. Table I shows a list of problems and the ranges in which vibration must be considered when high accuracy is desired. Research work is being continued to develop techniques for reducing the effect of vibrations.

TABLE I

Spans Below Which Vibration Effects Must Be Given Special Consideration

0 — 0.2% H_2O
0 — 0.1% CO
0 — 0.05% CO_2
0 — 0.1% of most Hydrocarbons

THE PROBLEM OF HIGH SELECTIVITY

The second type of difficult problem is the one which requires high selectivity. The analysis for 0 to 10 per cent iso-butane in a mixture of normal butane and the butenes would be such a problem. LIRA could then be sensitized as shown in Fig. 8.

An anayzer calibrated in this manner would be sensitive to iso-butane and to a lesser degree to the other butanes and butenes. The selectivity would not be sufficient to perform an accurate analysis unless the relative proportions of the background gases remained nearly constant. If the proportions of the background gases vary, the sensitizing techniques previously developed for the non-selective detector instruments are employed.

Fig. 9 shows how such an analyzer would be calibrated. This is the cancellation method of obtaining selectivity previously described. The concentration of the normal butane and butenes is adjusted so that these gases in the sample affect each beam equally. After this has been done the iso-butane still changes one beam more than the other. This technique provides suitable selectivity to make a satisfactory solution to this problem.

Representative applications for LIRA may be summarized as follows:

(1) Measurement of carbon monoxide in ammonia synthesis and in hydrogenation gases.

(2) Propane and butane content of natural gas.

(3) Water vapor concentration in process gases.

(4) Toxic gas detection.

(5) Measurement of reformer efficiencies, by analysis of compounds produced.

(6) Control of distillation operations.

(7) Control of the progress of the batch type operations.

Fig. 7.

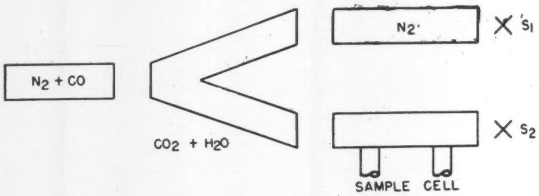


Fig. 8.

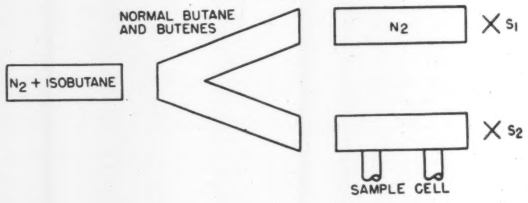
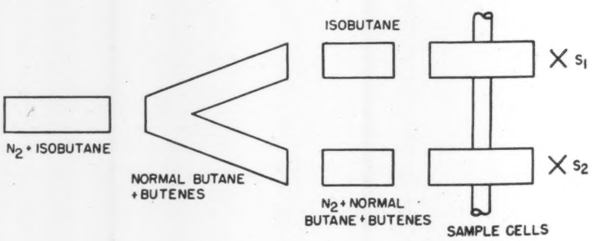


Fig. 9.



Analysis can not be performed for gases which have no infrared absorption. The non-absorbing gases are nitrogen, hydrogen, oxygen, chlorine, and the inert gases.

ANALYSIS OF LIQUID MIXTURES

In the past the majority of problems solved by non-dispersion infrared analyzers have involved gaseous mixtures. The analysis of liquid mixtures has recently become an important field. Several difficulties are immediately encountered when these mixtures are used. Liquid cells must be thin; they generally vary from 0.001 to 0.030 inches in thickness. LIRA is designed with liquid cells which function effectively with continuous flow samples.

When a selective detector instrument is used to analyze a liquid mixture, a problem is immediately encountered. A liquid cannot be put in the detector. It is, therefore, necessary to find a gas or vapor which will substitute as a detector. Such a gas can generally be found.

The measurement of impurities in water is extremely difficut because the liquid water is an intense absorber throughout most of the infrared spectra. This absorption is so strong that it generally masks the change in absorption by the impurity and thus makes analysis of impurities in water improbable.

Problems involving multi-component mixtures are very difficult. In general, liquids which are similar chemically exhibit less absorption differences than similar gaseous compounds. It is very difficult to obtain high selectivity in complex liquid systems. Nevertheless LIRA can satisfactorily solve many liquid problems.

The detection of water in alcohols, ketones, benzene and other hydrocarbons is practical. Measurement of hydrocarbon mixtures of alcohols and ketones, petroleum hydrocarbon mixtures and many other related problems is possible. Liquid problems are often encountered in the control of distillation and the control of product quality.

ACKNOWLEDGEMENT

The authors wish to express their appreciation for the assistance and support of those who have helped them in the development of LIRA. Without this assistance the accomplishment of these improvements would have been more difficult.

EMPLOYMENT SERVICE

Continued from page 615

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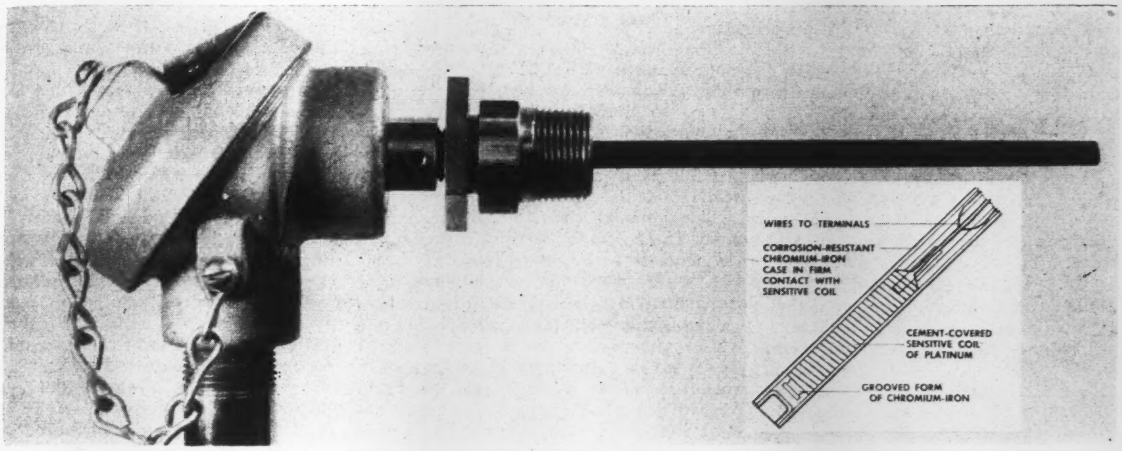
RESISTANCE THERMOMETRY

By ELMER W. HAYES
General Petroleum Corporation


WIRES TO TERMINALS
CORROSION-RESISTANT CHROMIUM-IRON CASE IN FIRM CONTACT WITH SENSITIVE COIL
CEMENT-COVERED SENSITIVE COIL OF PLATINUM
GROOVED FORM OF CHROMIUM-IRON

Straight-type "Thermohm" with universal head; protecting well not included.

Every phase of petroleum processing, from the drafting room through construction and operation, is affected by temperature. One of the oldest and most accurate methods of measuring temperature is resistance thermometry

PRINCIPLES AND TYPES

OPERATION of a resistance thermometer, or "Thermohm,"* depends on the variation with temperature of the resistance of an electrical conductor. Pure metals change in resistance when subjected to change in temperature. An industrial resistance thermometer should have (1) reproducibility and constancy of resistance and (2) a convenient and simple relation between temperature and resistance.

Platinum in its purest form has the most desirable properties for use in "Thermohms" up to a temperature of about 1000 deg. C. (1832 F.). When properly calibrated, a platinum resistance thermometer can measure to an accuracy of 0.05 C. degree. For industrial work, the platinum "Thermohm" is used between minus 40 and plus 800 deg. F.

Nickel has a desirable relation between temperature and resistance in lower temperature ranges. As nickel is more economical than platinum, it is used for "Thermohms" between minus 240 and plus 250 deg. F. Copper also is used between 0 and 350 deg. F.

Resistance thermometers can be used where the temperature limits are within the suitable ranges, and where it is possible to protect the element from contaminating gases and excessive vibration. Since its introduction by Siemens about 1871, and its improvement by Callendar in 1886, the resistance thermometer has been adapted for many uses, including use as a primary standard between minus 40 and plus 450 C. (minus 40 and 842 deg. F.), measurement and control of temperature on aircraft, petroleum processing, air conditioning, refrigeration, and for any service where it is desirable to measure or control temperature with high accuracy. It is possible to indicate a differential temperature with an accuracy in the order of 0.0004 deg. F. with resistance thermometers.

CONSTRUCTION AND CALIBRATION

Resistance thermometers can be constructed in various ways. Probably the most common type used in petroleum refining is the 7½-inch platinum "Thermohm," which usually is made with about 24 inches of No. 39 selected platinum bare wire, wound on a mica unit about 3 inches long by 5/16 inch in diameter. The unit is built up on two pieces of mica, arranged to form a cross. The wire touches only the edges of the mica.

The winding is done so that the start and finish of the unit are in the same general area. This prevents temperature gradients from producing any thermocouple effect. For like reasons, the extension wires from the platinum unit to the terminal head are made of

---

*Trade name, Leeds & Northrup Co.
Presented before the Southern California Meter Association.

gold or platinum in precision standard units, or of chromel in industrial units.

The wire is wound on the cross and spot welded to the terminals in its protector tube, which is about ⅜-inch-o.d. thin-wall nickel-tubing. The unit then is placed in a standard steam bath at atmospheric pressure. A reading is observed at approximately 212 deg. F. and is compared with the reading of a secondary standard in the same bath. The *difference* between these readings is recorded as one of the tie (reference) points of this unit with respect to the standard curve. The procedure then is repeated in an oil bath near 600 deg. F., and the differential is observed and recorded as a second tie point. The tie points are compared with a standard curve.

If the differential at 212 deg. F. is minus 35 deg. F., and if at 600 deg. it is minus 50 deg. F., this indicates that the unit being calibrated must be made shorter by cutting out a small piece (about ⅛ in.) of platinum wire in the unit. The above tests are repeated and additional cuts are made until the differentials are equal at each tie point. This means that the curve for the unit being calibrated is now parallel with that of the standard unit. The differential between the two curves can vary between 30 and 60 deg. F., depending on the characteristics and properties of the platinum being used.

In order to shift the curve so that it falls on the standard curve, it is necessary to place a short length of manganin (zero-coefficient) wire in series with the "Thermohm." This resistance is adjusted to make the unit read the same as the standard and is usually silver soldered to the terminals on the inside of the terminal head. There are four terminals, one for each of the *A*, *B*, and *C* legs of the "Thermohm," and one for the pad coil, so that the differential can be changed at any future calibration. This two-point check is adequate for "Thermohms" used in the middle temperature ranges. Where high accuracy is needed throughout the full range, the practice is to calibrate at three points—ice point, steam point, and boiling point of sulphur.

These calibrations can be made with a Leeds & Northrup resistance bridge, using two slide wires arranged to give a constant one-to-one ratio (Fig. 1). The slide wires S and S_1 rotate together on the same shaft. Their resistances are proportioned by the contacts V and V_1 on the slidewires so that a constant one-to-one ratio is obtained on the two arms of the bridge. The resistance of arm VV_1 is always equal to the resistance of arm V_1A_1. The bridge is brought to balance by rotating the slides until the resistance arm VRC is equal to the resistance of T (the "Thermohm"). With this circuit, the resistance of the leads from R to T and from A_1 to T have no effect on the reading as long as these leads are of equal resistance.

As contacts V and V_1 are not in the measuring circuit, contact resistance at these points has no effect on the accuracy of the reading. Likewise any normal variation in battery voltage does not affect the reading.

MEASURING METHODS

The bridge method of measuring temperatures (Fig. 1) often is desirable because it is possible to design the bridge so that the full-scale range is in the order of 20 deg. C. and, operating over such a narrow range, it is possible to measure and control accurately.

The general principle of measurement is the same with all resistance thermometers; however, there are various other types of instruments used for measuring the change in resistance.

The *potentiometer method* is one where the resistance is expressed in terms of a standard resistance, the ratio of which depends on the ratio of the potential drops across two resistances when carrying the same current (Fig. 2). In this circuit the variation of resistance of the connecting wires has no effect on accuracy. As a constant current is necessary, this method is not used as often as the balance, or bridge, method.

The *deflection method* can be used in unbalanced bridge circuits with reasonable accuracy, or in a circuit where the "Thermohm" is placed in series with a galvanometer and regulated battery voltage. However, when the deflection method is used, one must depend on the accuracy of the current-driven movement of the galvanometer. In the null method of reading, as in the balanced-bridge and potentiometer types, the reading is taken at zero current, which seems to be the most widely used system.

INSTALLATION AND MAINTENANCE

The instrument should be installed where it is reasonably free from dirt, oil, and excessive vibration. The connecting wires to the "Thermohm" should be pulled in a conduit in a careful manner so as not to change the resistance of the wires during installation. All splices should be carefully soldered because a change of resistance in the order of 0.018 ohm means one degree error in the 10-ohm platinum "Thermohm" described. The Siemens three-wire method of compensation allows lead wires of considerable length. This system employs a bridge of constant one-to-one ratio, the *A* and *B* leads to the "Thermohm" being extensions of the bridge arms. If both these leads are the same resistance and are pulled in the same conduit, they have common changes in resistance due to temperature changes along the conduit run. Such leads can be extended without changing accuracy, but with a loss in sensitivity which can be compensated for by raising battery voltage. Battery voltage should, however, be low enough that the current through the measuring coil does not generate enough heat to affect the calibration.

The lead wires can be checked one at a time with a standard check coil designed to work with the instrument to be used. It is connected to the "Thermohm" end of the circuit and a reading taken with the instrument. It should read the temperature indicated on the check coil if the *A* and *B* legs of the circuit are of equal resistance. If it reads high, it means that the *A* leg is higher in resistance than the *B* leg. This, of course, is true if the instrument has been checked with the check coil connected directly and found to be correct.

You may sometimes find that two of the three wires will be of equal resistance; the one that is "off" can be used for the *C* leg. If this is not the case, then after you have proven to yourself that you are not padding an intermittent circuit, you can pad the *A* or *B*

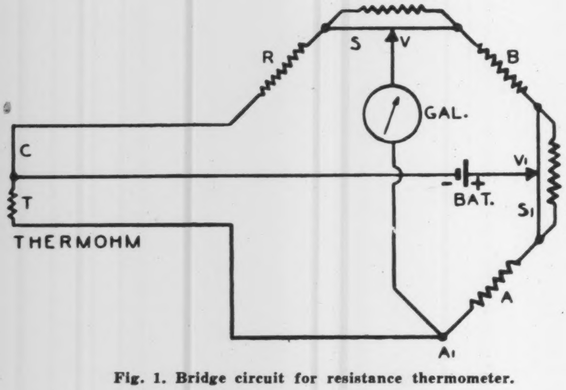


Fig. 1. Bridge circuit for resistance thermometer.

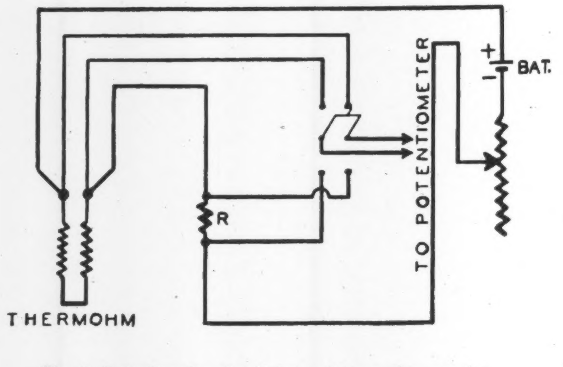


Fig. 2. Potentiometer circuit for resistance thermometer.

circuit with manganin wire to make them of equal resistance. It is seldom necessary to pad very much when care has been exercised in the purchase and installation of the wire.

The instrument and circuits can be checked periodically with a check coil, which detects worn slidewires, faulty circuits, and lack of sensitivity. This check coil is a noninductive coil wound with manganin wire to an ohmage that meets the specifications for a designated temperature within the range of the instrument being tested.

Multipoint instruments of the resistance type have selector switches that are operated either manually or by motor. These switches must be kept clean and well lubricated by a clean non-corrosive oil because this switch normally switches the *A* and *C* circuits, and any change in contact resistance introduces eror in the readings.

A spare point on the instrument connected to a check coil can serve as a continuous check on the over-all accuracy of the instrument.

ADVANTAGES

1. Can be designed to have a greater accuracy than other types of temperature-measurement instruments.
2. Greater distance allowable between instrument and "Thermohms" than with direct expansion types.
3. Lower temperatures can be measured than with pressure-type thermometers.
4. Can be used effectively in the range of normal ambient temperatures where the thermocouple is not dependable.
5. Not critical to normal changes in operating voltage.
6. Requires no cold-junction correction.
7. Cost of copper leads is less than compensating lead wires.

DISADVANTAGES

1. Initial cost.
2. It is affected by excessive vibration.
3. Platinum absorbs metallic vapors when operated at temperatures high enough to show color—approximately 900 deg. F. This alloys the platinum and changes the calibration. In this it is similar to any platinum thermocouple and, if protected by proper ceramic tubing, a "Thermohm" can be used at elevated temperatures.
4. The necessary precautions in the extension lead wires.

June Meeting: Thursday, the 19th, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30, meeting at 8:00 P.M.

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pH MEASUREMENT

Continued from page 605

just the instrument to read this pH. This is known as "standardization." It is necessary because each glass electrode has a residual potential called its *asymmetry potential,* or simply "AP." In the manufacture of Beckman glass electrodes this AP is held within a tolerance of ± 12 mv. The AP adjustment changes the point of zero input to the instrument, but does not change the slope of the emf.-pH curve. In an installation with six electrode stations, the AP adjustment is made by using the controls of the multiple switch. With one set of electrodes this adjustment would be made at the instrument by means of the No. 2 control of the pH indicator.

Note that the pH instrument chosen for this installation (Fig. 7) is calibrated from 3 to 10 pH and the recorder is calibrated from 2 to 12 pH. This extra recording range is gained because the amplifier of the "Model R pH Indicator" is linear 1 pH below and 2 pH above its calibrated meter scale. Of course the right combination of plug-in resistor and recorder are necessary; for example, if the "Model R" had an output of 0 to 35 mv., the recorder required would be −5 to +45 mv. With these values the recorder would read 3 pH with a 0-mv. input and the output of the "Model R" would be 0 mv. at 3 pH. The signal developed by the "Model R" and required by the recorder would be 5 mv. per pH.

TROUBLE-SHOOTING

The first part of trouble-shooting a complete pH installation is to isolate the problem to one of the individual parts—pH instrument (amplifier), recorder, electrodes, multiple switch, connector box, or cables.

Recorder

If the pH instrument has an indicator, as is usually the case, the recorder is easily eliminated by comparing the recorded value with the indicated value.

Amplifier

The amplifier of the pH indicator also can be eliminated by determining whether the trouble is encountered before or after the electrodes are introduced into the circuit. If in the "Beckman Model R" the operating difficulty is noted when the selector switch is in the No. 1 or No. 2 position, it is then a fault of the amplifier. Grid current or leakage current in the amplifier can be checked with a shielded resistor of about 10,000 megohms. This resistor is substituted in place of the short-circuit strap; any current flow through it then appears as a voltage drop across the resistor.

Electrodes

The glass and reference electrodes can be checked easily and conclusively by substitution after first making sure that the electrodes are clean.

Glass electrode. If the glass electrode is not performing properly, the cause generally is: (1) Scratched or cracked pH-sensitive tip, (2) broken internal assembly, (3) damaged cable, (4) faulty connection to the pH instrument, or (5) "aging" of the pH-sensitive tip after prolonged service. In the first three, the glass electrode must be replaced. In 4, cleaning and drying the connections should remedy the trouble. In 5, alternate immersion (cycling) in acid and alkali or, in extreme cases, a light fluoride etch generally returns the electrode to optimum condition.

Reference electrode. Improper performance of the reference electrode usually can be traced to one of the following: (1) Broken internal assembly, (2) contamination of the internal solution, or (3) impaired liquid junction. In the first, replacement must be made. In 2, if the reference electrode is a fiber type, replacement is advisable; if the electrode is a sleeve type, repeated flushing with saturated KCl solution and final refilling often returns the electrode to service. In 3, with a fiber-type electrode, any impairment is probably due to plugging of the fiber junction, and can often be remedied by soaking in a suitable solvent, or, in extreme cases, lightly grinding the tip with a fine abrasive. In 3 with a sleeve-type electrode, momentary flushing by unseating the sleeve is often sufficient. If the sleeve becomes stuck, short immersion in warm KCl or, if necessary, in warm water, usually loosens the sleeve.

Resistance Thermometer

Aside from occasional removal of excessive deposits on the resistance thermometer, which may act as thermal insulation, the resistance thermometer requires no maintenance and should operate indefinitely unless the glass jacket is cracked. A standard ohmmeter can be used to check the resistance thermometer for continuity.

Other Elements

Connector boxes, connecting cables, and multiple electrode switches can be checked by balancing the instrument with a short-circuit strap, installing a 10,000-megohm resistor, and noting the change in reading of the pH indicator or recorder.

Test Equipment

Trouble-shooting the amplifier and recorder requires the same test equipment as for other types of electronic equipment. For work with a complete pH installation, the serviceman also should have a short-circuit strap, 10,000- and 20,000-megohm resistors, and a portable pH meter.

QUESTION AND ANSWER PERIOD

1. *Question*: Are pH meters self-standardizing? *Answer*: No self-standardizing pH meter has yet been produced commercially.

2. *Question*: At what pressures can this equipment be used? *Answer*: The limiting factor is the reference electrode. The new Beckman "diver's bell" design electrode can be used from vacuum to 30 psi., and special electrodes of this same design can be made for use to 100 psi. and higher.

3. *Question*: If the temperature of measurement can be selected, should it be high or low? *Answer*: Keep temperatures for pH measurement low if possible. Room temperature is the most convenient.

4. *Question*: Can the lead on the resistance thermometer be shortened? *Answer*: Yes. Leads in both reference electrodes and resistance thermometer are not highly shielded and can be cut and spliced like electrical wiring. The glass electrode lead, however, is specially shielded and should never be cut or spliced by the user.

5. *Question*: What is wrong if the pH meter reads 6 pH no matter what media is tested from 7 to 14 pH? *Answer*: The pH-sensitive glass tip of the electrode is cracked or broken. In such a case, the meter will always read a constant value (around 6 pH) regardless of the actual pH of the sample.

CAPACITOR-CHARGING CIRCUITS

Continued from page 599

across V4 and V5 falls to the extinction value, and the tubes no longer conduct. C2 recharges through V3 and R2 until its terminal voltage reaches the supply voltage less the extinction voltage of V3, at which time V3 goes out, and the total drain on the system again becomes only the current through V2.

Of the three control systems, the one in Fig. 3 requires the most equipment between the filter output and the thyratron plate. However, it provides the best regulation for capacitor charging, and places the smallest surge loads on the main power supply. During 11 months of operation, this circuit has required three new 2050 and four OD3/VR-150 replacements. All other components are still in service. Count rate averages 40 cpm., with the random pulse-spacing characteristic of cosmic-ray impulses.

REFERENCES

(1) Ives, R. L., "Capacitor-Discharge Recorder Applications," *Electronics*, Vol. 22, No. 2, 1949, pages 104-108.

(2) Ives, R. L. "Geiger Counter for Lectures," *Electronics*, Vol. 23, No. 7, 1950, page 118 et seq.

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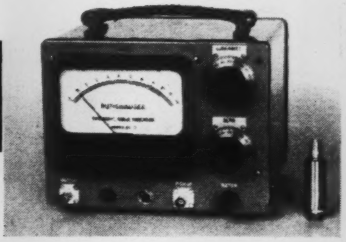

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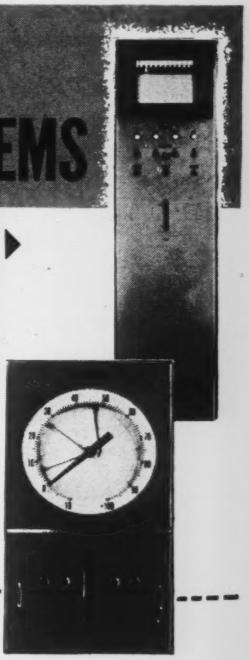

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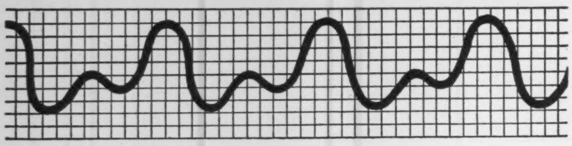

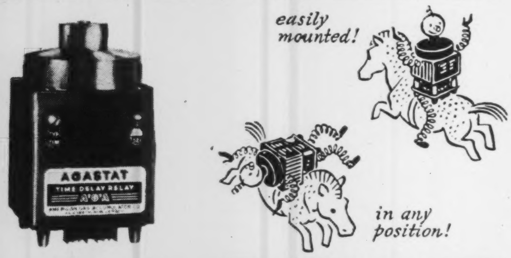
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VALVE CONTROL

Continued from page 598

substituting actual flow rates for percent of flow under the extremes of ideal (0:1) and maximum-tested (1:0.5) drop ratios. To maintain a specific rate of controlled flow, the valve stroke must change by relatively small increments in the equal-percentage valve; by somewhat larger increments in the parabolic; and must assume widely different positions with the poppet up to 70 percent of its limited stroke. Above this point the percentage change in flow is small.

EFFECT OF OVERSTROKE

All the valves were overstroked by 10 percent to establish the characteristic and the percent increase in flow above the rated capacity. Typical "increased" capacity was the 20 percent obtained for the 1-inch equal-percentage, but the exponential characteristic was no longer evidenced. The 1-inch parabolic gained 2 percent in rated capacity. The 1-inch poppet valve was stroked one-fourth of the nominal valve size for 100-percent lift, and the capacities reported are on this basis. It gained only 1 percent on a 10-percent increase in stroke. The increase in the equal-percentage valve brings it approximately to the capacity of the parabolic. Control valves are *not*, in the primary analysis, high-flow-capacity devices, but are designed for characterized throttling service.

EFFECT OF PUMP

The condition of a fixed upstream pressure is not the most common one met in industrial flow control. Instead, the source is often a centrifugal pump. Fig. 6 shows the pump characteristic. As the rate of flow increases, the pump discharge-pressure decreases. This droop of the pump curve affects the system flow pattern and distorts all valve characteristics. Because of the pump's capacity-head curve we were unable to obtain high drop-ratio across the 2-inch poppet valve and to deliver flows up to maximum capacity of the valve.

Fig. 7 shows how the design characteristic changes under *direct pumping* conditions. The effect is drastic. Note that the slope and sensitivity of the equal-percentage valve is more constant than the other two. The parabolic type loses effectiveness above 55-percent lift; the poppet is definitely limited to 40-percent lift.

The drop ratios in all direct pumping runs for the equal-percentage valves were 1:2—in other words, 67 percent of the available pressure drop was across the valves in the wide-open position; 1:1.1, or 52 percent, for the parabolics; and 1:0.85, or 46 percent, for the poppets.

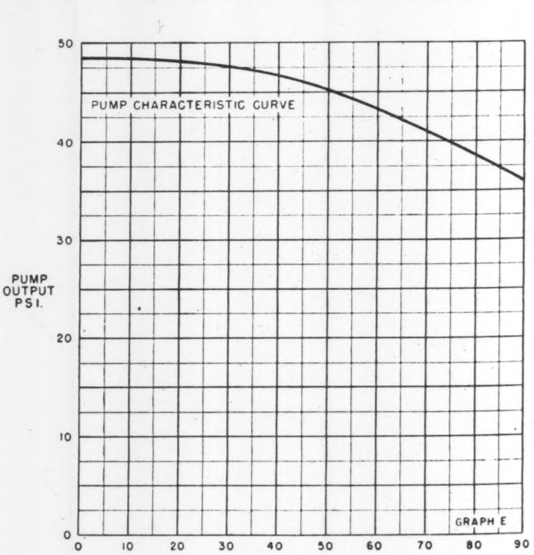

Fig. 6. Characteristic curve of a centrifugal pump.

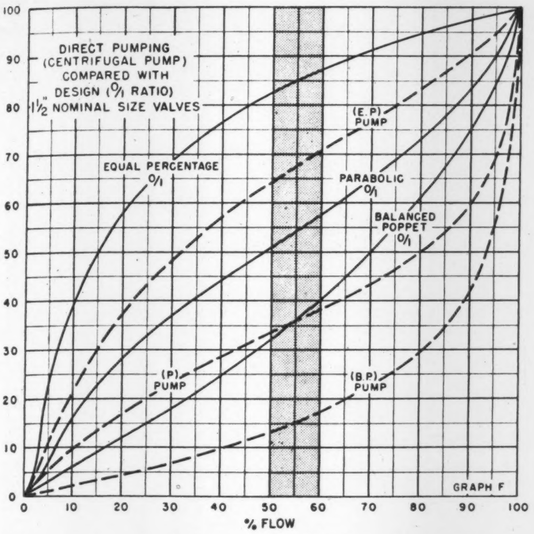

Fig. 7. Change in characteristic curves when direct pumping is used.

PRESSURE DIFFERENTIAL

We have considered flow and lift in our curves. Flow is, of course, the ultimate feature of interest in process work, but within the flow-control loop the *pressure differential* is the actual working term. That is, most flow controllers, and especially those responding to a pneumatically transmitted signal, operate directly from the pressure differential existing at the primary element. Thus, the sensitivity of the system is defined more accurately for controlling purposes by differential vs. lift, rather than flow vs. lift. This concept is important in that it is basic in understanding the sensitivity (proportional-band) needs of the controller in a flow-control system. Fig. 8 illustrates the important interrelationship between flow, orifice differential, and valve lift. The arrangement shown in Fig. 8 is theoretical and, of course, assumes hysteresis-free mechanical components.

The square-root relation between flow and differential changes the shape of the valve characteristics as shown in Fig. 9, which duplicates the data in Fig. 4. A scale of valve-motor pressures (for standard pneumatic operating range of 3 to 15 psi.) has been added to the lift scale. This assumes a linear pressure-versus-motion response. Such response is available in standard equipment and is shown by the straight-line curve of lift vs. valve-motor pressure in Fig. 8.

The curves in Fig. 9 illustrate the effect of various drop ratios on the design characteristics of the different valve types from the control point of view. The equal-percentage type effectively resists serious distortion and equal percentage changes of air pressure produce flow changes that do not deviate too seriously from the designed exponential

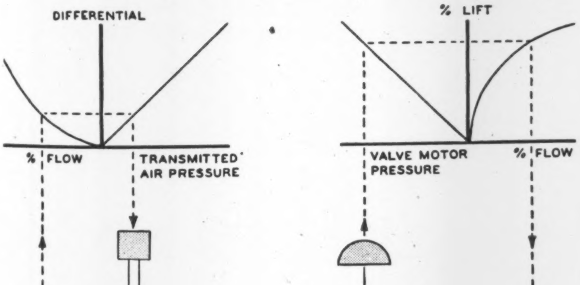

Fig. 8. Relationship between pickup and control-valve characteristics in a flow-control system.

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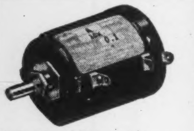

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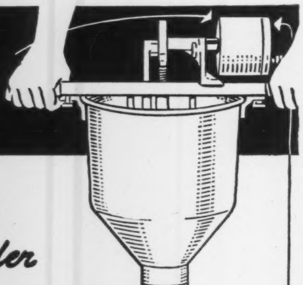

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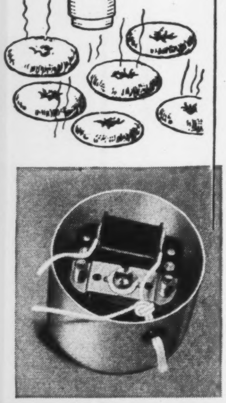

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shape. However, the valve becomes *less sensitive* through a greater portion of its stroke. The parabolic and poppet become *more sensitive*, with the latter showing best linearity of characteristic. At the same time, however, the poppet shows the greatest deviation from its design characteristic.

FLOW CONTROL

Fig. 10 shows the effect of direct pumping on the differential-lift characteristic. Let us consider the possibility of selective application of the various types on the basis of careful sizing. We can now reach the following conclusions regarding flow control from the curves in Fig. 10:

(1) The poppet-type valve has the most linear flow (or differential) vs. lift (or air-pressure) characteristics under conditions of relatively small drop-ratio changes and is *theoretically* the most suitable commercially available valve. The sensitivity, or flow-lift ratio, increases with less favorable drop-ratio or in direct-pumping operation.

(2) Careful sizing is required to utilize the poppet to best advantage from the most effective lift (or air pressure) point of view. This is shown in Fig. 10, which shows

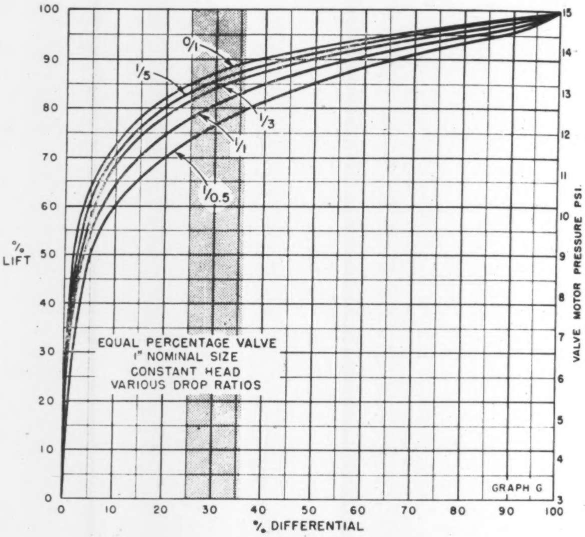

Fig. 9A. Valve characteristics, in terms of lift versus pressure differential, for equal-percentage valves.

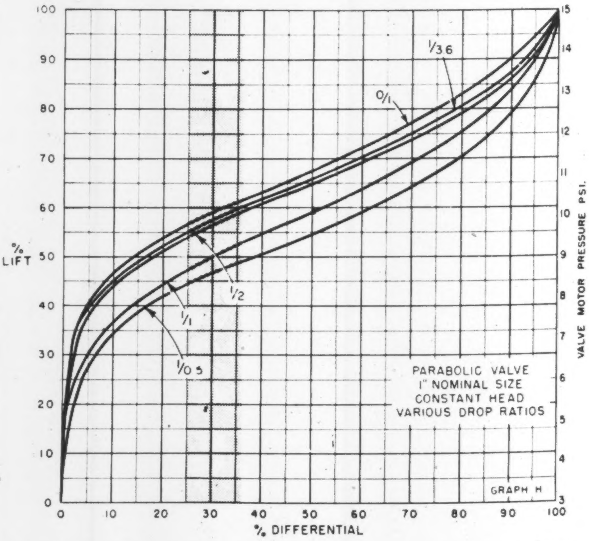

Fig. 9B. Valve characteristics, in terms of lift versus pressure differential, for parabolic valves.

what occurs in field application. For a given flow the valve drop must remain reasonably constant to secure the advantages of this type valve.

(3) The parabolic valve shows good linearity of operation in the middle portion of its stroke (differential from 15 to 85 percent), but the flow-lift ratio decreases rapidly at either end. In the middle section the flow-lift ratio increases with unfavorable drop-ratio or with direct-pumping operation.

(4) The equal-percentage valve has a zone of relatively linear response at the upper end (25 to 95 percent) of the differential scale. It resists departure from the design characteristic more effectively than the other two. This type maintains its characteristic more nearly constant than the others and, therefore, makes controller settings relatively independent of supply and demand conditions once the settings are established for the operating rate.

(5) The constancy of sensitivity of the equal-percentage curves provides wide rangeability of control and, as compared to the poppet, reduces the necessity for great care in narrowly establishing the available pressure-drop assignable to the control valve.

(6) Good flow control, from the practical point of view,

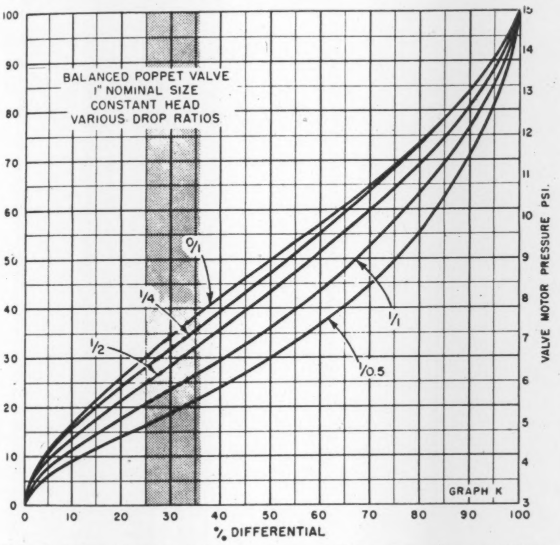

Fig. 9C. Valve characteristics, in terms of lift versus pressure differential, for balanced-poppet valves.

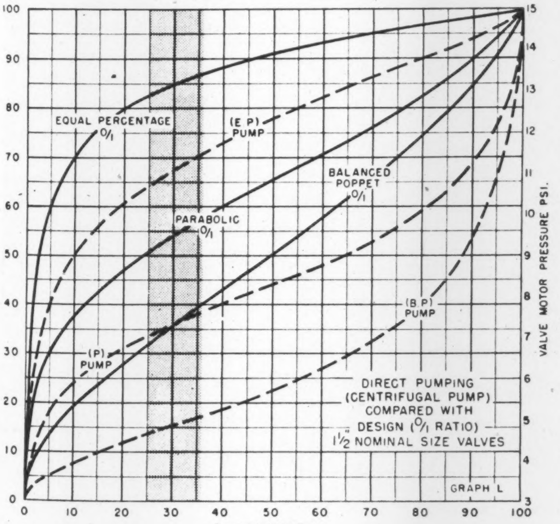

Fig. 10. Differential-lift characteristics of valves used in system with centrifugal pump.

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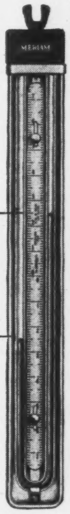
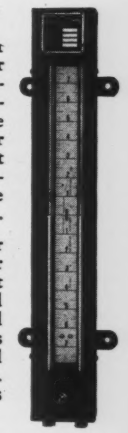
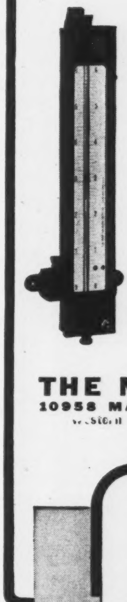




U-TYPE MANOMETERS

The Clean-Out Manometer (at left) for line pressures up to 100 lbs. per sq. in. A wing nut permits the Manometer body and tube to be disconnected from the head — the tube cleaned with a brush furnished or tube replaced, and the instrument reassembled without disconnecting the head section from the piping. Send for Bulletin No. 1.

The Model A-995 WM Manometer for line pressures up to 400 lbs. per sq. in. These instruments are built with heavy walled annealed straight Pyrex tubes, gland packed top and bottom in steel end blocks and clamped to the body at fixed intervals to prevent distortion. Catalog Sheet A-995 WM gives complete details.



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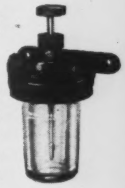

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is obtained with the equal-percentage type despite the fact that it does not satisfy theoretical ideals. This is because most changes of controlled flow rates are limited.

(7) Obviously, the more accurately the valve can be sized, the better. However, the situation can arise where it becomes necessary to operate the process in ranges above or below the design level. Changing the range of the primary element may be the only concession allowable to match the control equipment to the process change. The curves presented do not illustrate this situation. They are all set up on a basis of 100-percent lift producing 100-percent (of scale) differential and disregard the actual maximum flow ranges involved. The test runs were made with widely different total drops and, therefore, different maximum flows, but the same drop ratios produced similar characteristic curves. Owing to its constancy of sensitivity, the equal-percentage has the greatest tolerance to changing design ranges because it produces less change in the system sensitivity than do the other types.

(8) If standardization and interchangeability are important criteria, the equal-percentage can be used beneficially for general control installations.

SYSTEM GAIN

Fig. 11 relates the important controller factors (differential transmitted pressure and valve motor pressure) with the valve characteristics. The significance is essentially the same as that of previous curves; the poppet type again demonstrates the most linear response. This method of presentation has significant possibilities for control-loop analysis because the ratio of input-to-output air pressure, or *gain*, can be shown. The valve motor pressure (P_{vm}) is the input and the differential signal pressure (P_h) is the output. Thus the slope of the curve at a given differential ($\Delta P_h/\Delta P_{vm}$) represents the static gain of the system at the corresponding flow. The gain can be expressed also as $\%h/\%L$, where h is the differential and L is the valve lift.

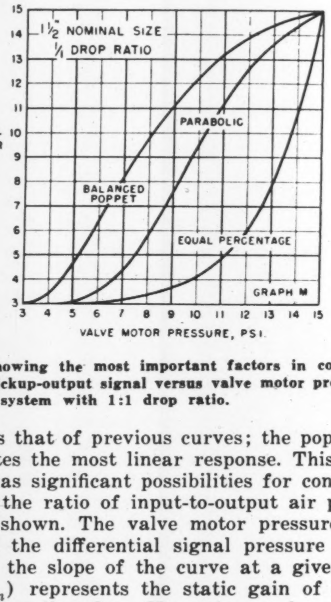

Fig. 11. Curve showing the most important factors in control-loop response—that is, pickup-output signal versus valve motor pressure for 1.5-in. valves in a system with 1:1 drop ratio.

The curves in Figs. 12 and 13 are plots of the slopes of the curves of Fig. 11—that is, plots of gain versus differential. They express the rate of change of differential signal that results from equal increments of change in valve-stem position at various points over the system operating range. The curves show the gain of equal-percentage and balanced-poppet valves. The performance of parabolic valves falls between these two.

Fig. 12 shows that the gain for the equal-percentage valve increases with differential all the way to 100 percent in ideal (0:1 drop-ratio) operation. A practical drop ratio, such as 1:1, causes the gain to reach a smaller maximum at about 75 percent of differential, and then to decrease as the differential increases thereafter. The reason for this change in action is brought out in Fig. 9A, where it can be seen that the 1:1 curve is inflected upward again at its right-hand end to counteract the general sag of the curves that takes place with increasingly unfavorable drop-ratio.

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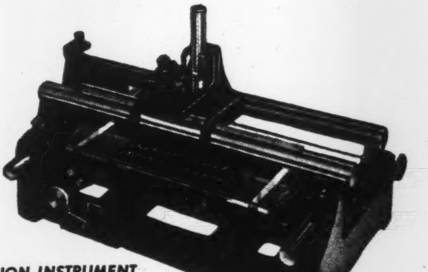

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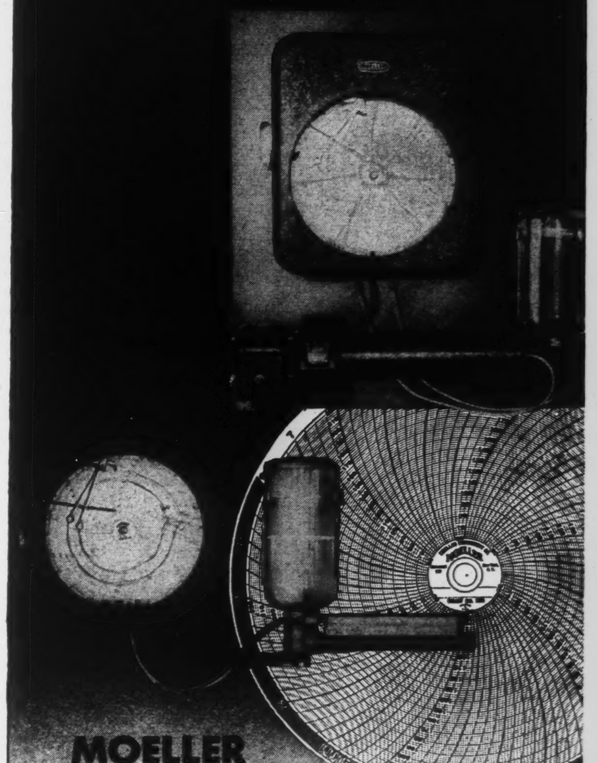

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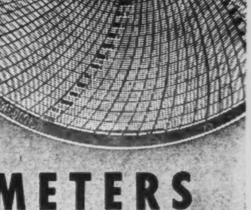

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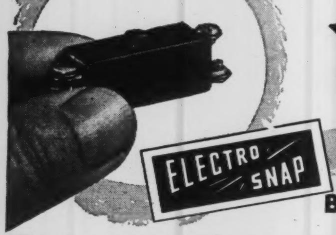

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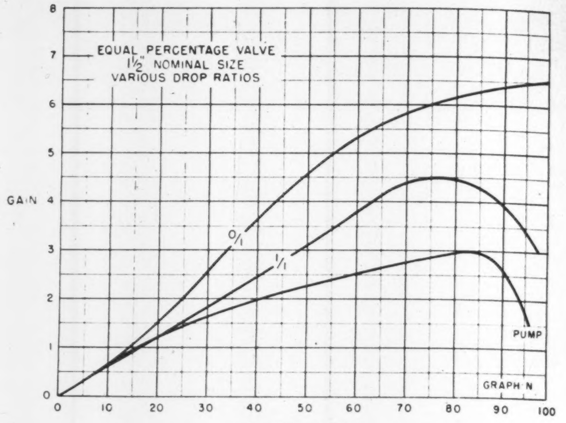

Fig. 12. Gain curves of equal-percentage valves in systems with various drop ratios.

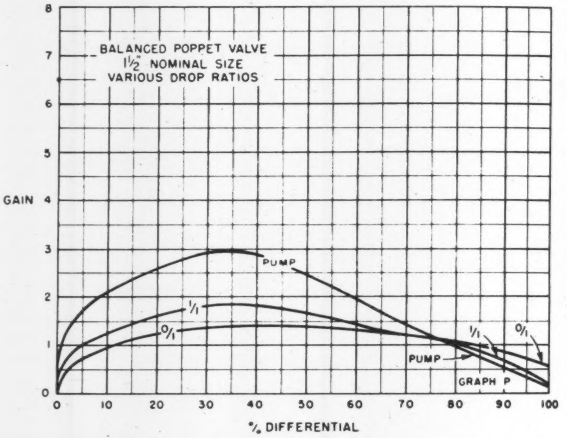

Fig. 13. Gain curves of balanced-poppet valves in systems with various drop ratios.

The pump curve in Fig. 12 shows that direct-pumping operation causes high departure from the ideal and reduces gain greatly when equal-percentage valves are used.

In contrast, the balanced-poppet valve under the same conditions (Fig. 13) shows an increase of gain with change in drop ratio. Reference to Fig. 9C provides an explanation. As the ideal (0:1) curve is inflected upward with increasing deflection (except for a short section at the low end) the sag with less desirable loading conditions moves the central portion in the direction of higher gain. This becomes emphasized in direct-pumping operation.

This concept of gain is a preliminary to the determination of the proper adjustments of a controller to be used with a given flow system. As these gains are static (steady-state) values, they are maximal and are modified greatly by the dynamic response of the system. To examine dynamic response, the system can be said to include the pneumatic transmission lines, valve motor, and other pneumatic equipment in addition to the controller proper. As one approach to control study, all the above can be considered to be parts of the "process." The development work that has been done so far, as outlined in this article, forms the basis for one part of the determination of the ideal controller for a liquid-flow process. It is the fourth in a series on the continuing work on our flow-control project.

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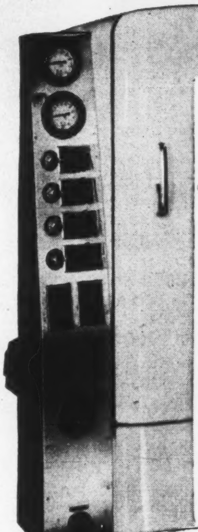

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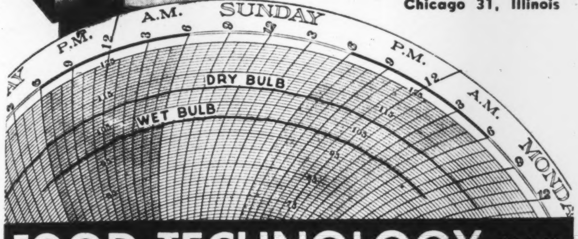

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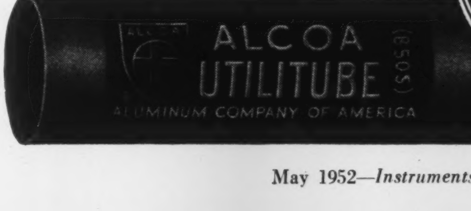

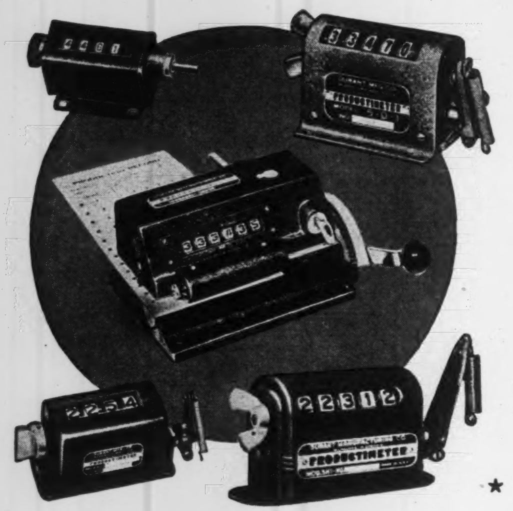

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HERSCHEL-VENTURI

Continued from page 565

of such a relation remains obscure, as can be inferred from Mr. Partridge's article; somewhere near the beginning of the present century.

Although one of Venturi's sketches shows a remarkable resemblance to the present-day so-called Venturi Tube, it simply illustrated the relative heights to which he found mercury was drawn up in vertical tubes by a conical pipe discharging water. From this, he concluded (broadly interpreted) that increase in velocity through such a pipe is accompanied by decrease in head. That was all!

There is no obscurity about the invention, in 1886, of the Venturi Meter by Clemens Herschel: the record is voluminous. While hydraulic engineer of the Holyoke (Massachusetts) Water Power Company, supplying nearly one hundred small mill turbines, he recorded:

> "Many a time did I stand beside a pipeline and exert myself to invent how to force these pipes to reveal the secret of their hidden action."

For four years he studied the problem, referring to Bourdon's anemometer, Venturi's researches, and the experiments of James B. Francis on the most efficient design for expanding ajutages for turbines. Finally, he built, in his turbine-testing flume at Holyoke, a one-foot and a nine-foot diameter "Venturi Tube" and upon them conducted a very thorough and comprehensive series of calibrations. These calibrations are fully described in the 1887 *Transactions* of the American Society of Civil Engineers. The Society awarded Herschel the Rowland Prize and this was followed, a short time later, by the Franklin Institute's highest award, the Elliott Cresson Gold Medal.

The invention has been recognized as marking an epoch in the science of hydraulics and Herschel became known as "the man who made Venturi famous." January 27, 1946, the following editorial, entitled "Venturi and Herschel," appeared in *Engineering News-Record*:

> "This year is the 200th anniversary of the birth of the Italian hydraulician, Giovanni Battista Venturi. Among other things, he formulated the important principle that fluids under pressure, in passing through converging pipes gain speed and lose head, and vice versa for diverging pipes. We remember and applaud this scientific contribution of Venturi. But in doing so we must likewise give equal recognition to a great American engineer without whose efforts the name of Venturi would have been buried in oblivion. It was Clemens Herschel who in 1887 invented a measuring device that provided a practical application of Venturi's natural law, thus providing the world with a flow instrument that has no peer for simplicity, accuracy and ruggedness. 'Out of respect for Venturi's experiments,' wrote Mr. Herschel, the device was named the Venturi Meter. Thus with a display of self-effacement that is rare, Mr. Herschel coupled the name of a long-forgotten engineer with his invention and gave credit to the man who had pointed the way. Few men are endowed with the mental sagacity of a Herschel, but all might emulate his generous spirit; to be niggardly in sharing credit for professional achievements shows lack of character without which an engineer cannot truly discharge his complete responsibilities. Thus in honoring Venturi we find good reason to pay double homage to Herschel whose engineering contributions were second only to his respect for the efforts of others."

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WASHINGTON, D. C.—An instrument cable free of spurious electrical signals due to mechanical shock and vibration has been developed by Dr. T. A. Perls of the National Bureau of Standards' Office of Basic Instrumentation, according to Technical Report 1645. The mechanism of noise generation in instrument cables was investigated and a theory formulated. According to this theory, the noise signals are due to currents set up in the cable when static charges are separated at the surfaces of the dielectric (Fig. 1). To free the cable of these unwanted signals, it is only necessary that the inside and outside surfaces of the dielectric be entirely covered by a well-bonded conductive coating. The resistance of the conductive coating need not be especially low; a coating having a resistance of the order of 1 to 50 megohms per linear inch of cable reduces the unwanted cable signals by a factor of 500 or more. Various types of conductive paints, suspensions of graphite, and conductive rubbers that may be used for the conductive coating are available commercially, and several patents have been issued on methods for bonding such coatings to a cable insulator.

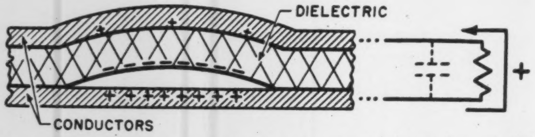
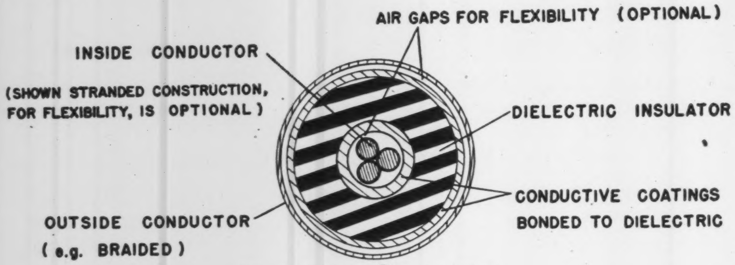


Fig. 1. Source of noise in cable is separation of charges at the surface of dielectric. The charge separation takes place whenever a metal makes intermittent contact with a dielectric.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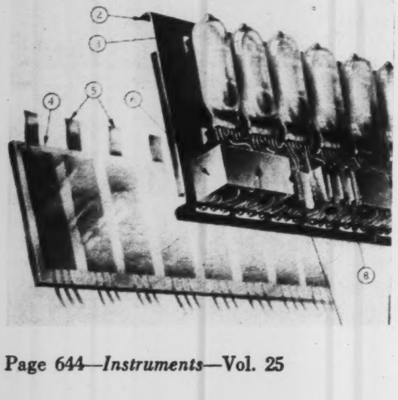

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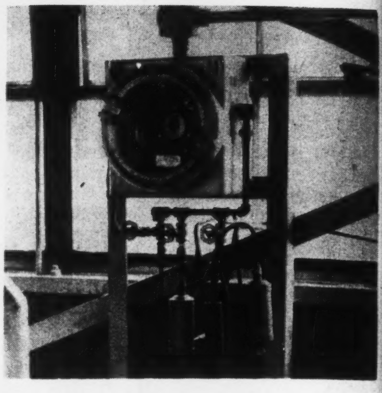

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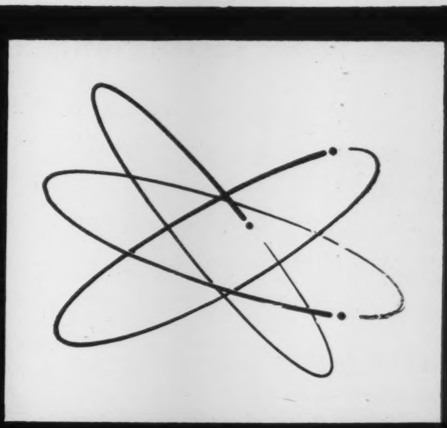

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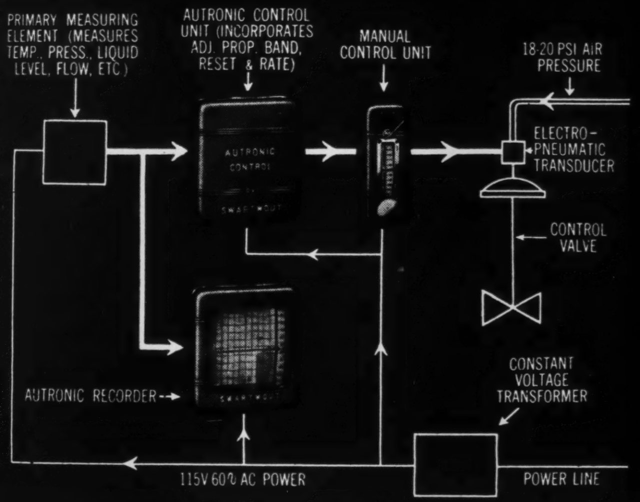
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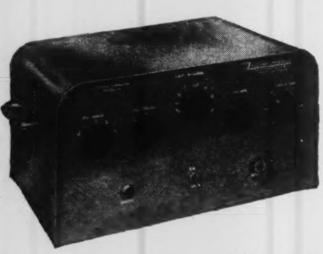

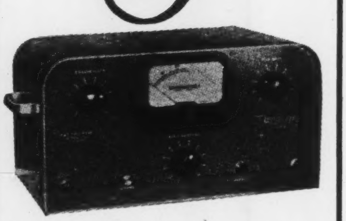

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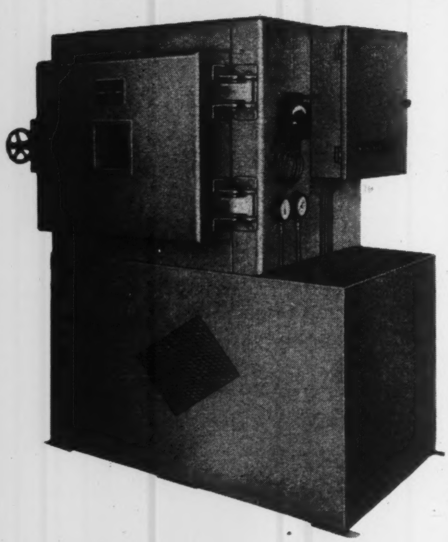

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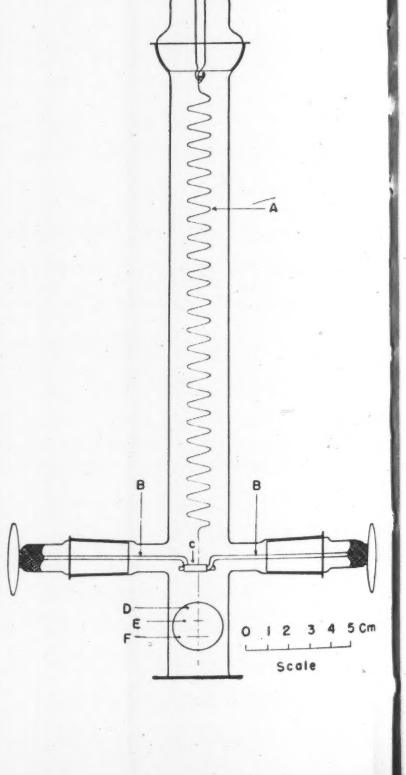
watch running more than a year. A synchronously controlled motor, powered by the capsule, replaces the mainspring and its associated parts. The winding mechanism also is eliminated. The watch was developed by the Elgin National Watch Co.

Vacuum Weighing Balance

WASHINGTON, D. C.—A simple tungsten-spring balance for weighing small quantities in a vacuum has been developed by Dr. S. L. Madorsky of the National Bureau of Standards, according to Technical Report 1658. Conventional helical-spring balances of fuzed quartz have not been entirely satisfactory; because of the low internal friction of quartz, the damping force is small and it took several hours for the spring to come to rest. The tungsten spring comes to rest in 10 or 15 minutes.

The balance consists of 23 turns of 3-mil tungsten wire (A), each turn having a diameter of about 1.1 cm. The spring is enclosed in an evacuated Pyrex tube and is suspended from a Pyrex rod attached to a ball joint at the top of the tube. The ball joint serves to center the spring in the tube. The material to be weighed is supported in a platinum crucible, weighing about 200 mg., which is attached to the lower extension of the spring (not shown). The weight of the container and contents is determined from the relative position of a crossline (E) on the spring extension with respect to a thin horizontal wire (F) attached to a flat glass window (D). Rubber friction clasps



(C), operated manually by rods (B), remove tension from the spring when it is not in use. The sensitivity is about 525 microns per mg. A sensitive comparator, reading to 1 micron, observes the change in position of the crossline.

Analytical Instrument Clinic

A lecture and demonstration course on analytical instruments—spectrometers, infrared analyzers, etc.—will be held in conjunction with the Seventh National Instrument Conference and Exhibit at Cleveland, Ohio, September 8 to 12, 1952. The Clinic is being sponsored by the Analysis Instrumentation Committee of the Instrument Society of America. Ten instrument companies will participate by supplying instruments and lecturers. The Clinic has been planned for technicians, chemists, physicists, and engineers of research and industrial establishments. It will cover electronic, optical, and mechanical design features, with emphasis on application details. Special maintenance classes will be organized for maintenance technicians if advance registration indicates sufficient interest. The program and registration forms may be obtained by writing to Axel H. Peterson, Mellon Institute, 4400 Fifth Avenue, Pittsburgh 13, Pennsylvania.

Texas A and M Symposium

The Agricultural and Mechanical College of Texas has scheduled its 1952 Symposium on "Instrumentation for the Process Industries" for June 2, 3, and 4, at College Station, Texas. Information can be obtained from Professor P. G. Murdoch, Chemical Engineering Department, Texas A & M College, College Station, Texas.

Summer Instrument Courses

U. of Minn.

A special summer course on Industrial Instrumentation and Servomechanisms is offered by the Mech. Eng. Dept. of the University of Minnesota Institute of Technology, Minneapolis 14, Minn. Morning classes will be held June 16 through July 11.

M.I.T.

Three summer courses are to be given at the Massachusetts Institute of Technology, Cambridge 39: (1) A course in Theory and Practice of Feedback Control Systems Engineering is to be given from June 9 to June 20. (2) A program in Digital Computers and Their Applications is to be given from July 21 to August 1. (3) A special course on the Theory and Applications of Dielectric Materials is to be given from September 3 to September 12.

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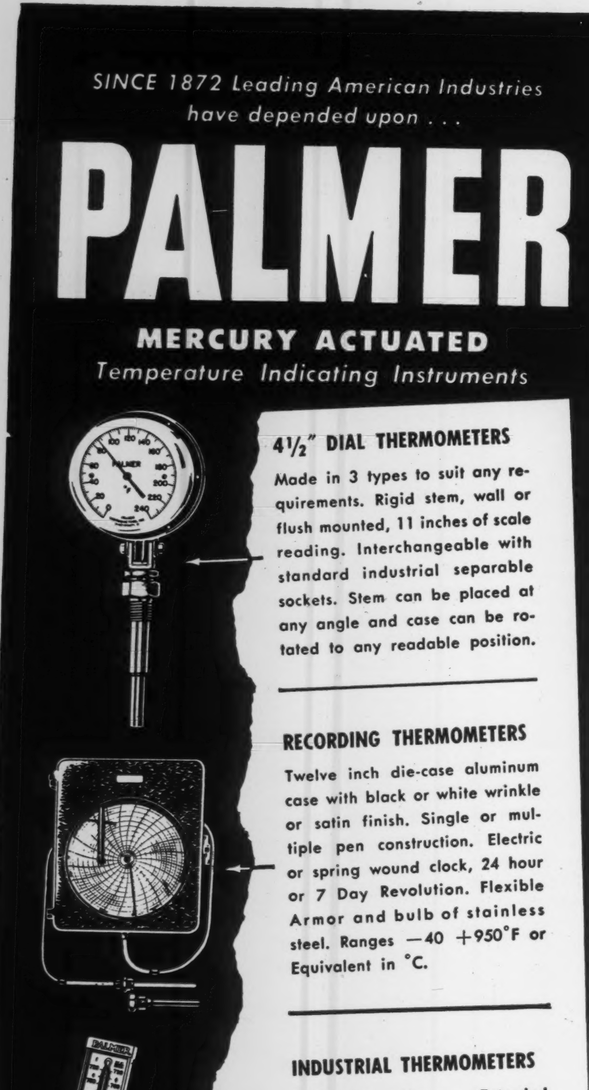

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INSTRUMENT ELECTRONICS

Continued from page 609

Note that the a-c. input is applied to the center leg. This saturates the core twice on each applied cycle—once at the positive peak and once at the negative peak. Any flux passing through the windings (for example, the earth's magnetic-field flux) cuts the output windings twice on each cycle—each time the core is *not* saturated. Thus a signal of twice the frequency of the applied a-c. signal appears at the output; the size of this output signal varies with the strength of the unidirectional applied flux and can be measured. This pickup element is used in flux-gate magnetometers.

The second-harmonic principle is used also in converting low-level d-c. signals into a-c. signals with a frequency of twice the applied a.c. Such a device is shown in Fig. 9-1.

Advantages

The advantages of magnetic amplifiers are: (1) they are solid and contain no moving parts or hot filaments—life expectancy is limited only by the rectifiers used, many of which are rated conservatively at 60,000 hours for full-power operation; (2) they are as rugged and as shock resistant as a similar-sized transformer; (3) they are relatively insensitive to power-supply variations and require no stabilized supply; current production models are available for 60, 400, 800, and higher cps.; (4) they can carry overloads as well as an equivalent transformer; (5) their power gain, which is comparable to vacuum tubes, can be cascaded to any value; (6) efficiency is higher than vacuum tubes; (7) the input and output circuits are electrically isolated; (8) their gain and shape are flexible; (9) the gain-control leads are less sensitive to pickup than are high-resistance circuits; (10) they can be hermetically sealed; (11) they require no warm-up time; (12) they have wide capacity—there is no theoretical upper limit to power-handling capacity, although the rectifiers impose a practical limitation; (13) they can amplify signals too weak to penetrate the emission shot-noise of vacuum tubes; and (14) they are stable d-c. amplifiers.

Disadvantages

The disadvantages of magnetic amplifiers are (1) the time constant (speed of response) is longer than that of vacuum tubes, although shorter than that of most electromechanical devices; (2) their upper frequency limit is about 500,000 cps. with excitation (source) frequency of 3 Mc. and time constant of 1 microsecond—eddy currents become serious at higher excitation frequencies; (3) the 60-cycle units are larger and heavier than competitive units, although size goes down as frequency increases.

Applications

The following are proven applications for the magnetic amplifier: (1) Amplifier for a-c. or d-c. current, voltage, or power, including amplification of d-c. thermocouple and photocell outputs to operate motors and controllers directly; the amplifier is more stable than many d-c. electron-tube amplifiers and has been used as seismograph and magnetometer amplifier; (2) their most common use is as regulators of voltage, current, and frequency of power supplies and generators; (3) as relay, either normally open, normally closed, or frequency sensitive, they are superior to conventional relays because they contain no contacts or moving parts; (4) as saturable reactors, they are used commonly for lighting control, motor starters, welding control, and battery-charging control; (5) current-limiting reactors to prevent over loads during short circuits or stalled follow-up motor; (6) complete servosystem; (7) computer component, including impulse storing, memory device, adder, subtracter, multiplier, divider, differentiator, and integrator; (8) d-c. to a-c. or a-c. to d-c. converter; and (9) high-power modulator or trigger circuit, as in radar modulators.

Ceramic-core Inductor

One type of magnetic amplifier, marketed under the trade name of "Increductor," uses a ceramic core with unusual magnetic properties. The core is not saturated, but the

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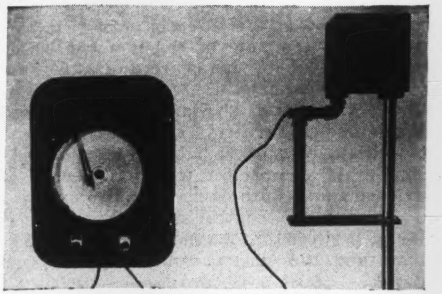

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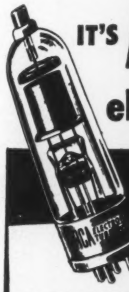

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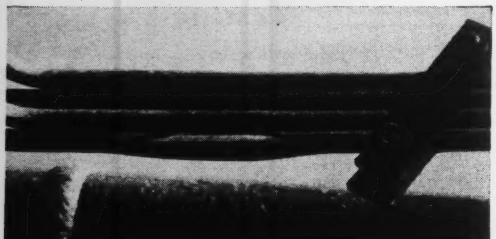

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permeability of the core is changed linearly by current in the control winding. The basic advantage claimed is a higher frequency response than is possible with the saturating-type magnetic amplifier.

DIELECTRIC AMPLIFIERS

The dielectric amplifier, the newest of the solid-state devices, is essentially a controllable capacitor. The control is exercised by changing the dielectric constant of the dielectric, which usually is a ceramic. Conventional ceramic-dielectric capacitors are now in common use because the high dielectric-constant of many ceramics permits high capacitance in small volume.

The dielectric amplifier is similar to the magnetic amplifier in principle and in circuitry. The magnetic amplifier is an inductor with a core of variable permeability; the dielectric amplifier is a capacitor with a dielectric of variable dielectric constant. Both devices require an a-c. supply, and both use a small d-c. control signal. Fig. 9-6 shows the close similarity between the magnetic amplifier, the dielectric amplifier, and the electron-tube amplifier (with a-c. supply).

Principle

The capacitance of a conventional capacitor depends on the dielectric constant of the capacitor dielectric, as explained in chapter 2. A conventional linear capacitor must have a dielectric of unchanging dielectric constant.

The inherent nonlinear characteristics of certain dielectrics have been known for many years, but only recently have they been put to use in dielectric amplifiers. These nonlinear materials include barium titanate, strontium titanate, lead zirconate, and various other ceramics. These dielectrics have a "hysteresis" loop that is very similar to the hysteresis loop of magnetic materials—that is, when a curve is drawn of electric field strength (in the dielectric) versus applied charge, a curve shaped like that in Fig. 9-5 is obtained. The curve in Fig. 9-5 is a ferro-magnetic phenomenon; the equivalent capacitor curve sometimes is called a *ferroelectric effect.* This term is misleading and confusing because there is no ferrous reaction in the capacitor, the dielectric has no metals in its construction.

The operation of the dielectric amplifier depends on the nonlinear characteristic of charge versus field strength. A small control signal (charge) changes the dielectric constant of the dielectric, permitting more or less of the a-c. supply current to flow through the load, which is in series with the supply (Fig. 9-6,C).

Curie Point

Many ceramic materials have a dielectric constant that changes rapidly with temperature, and reaches a maximum value at one temperature. The temperature at which this maximum dielectric constant is reached is called the *Curie point.* It is desirable to operate a capacitor at the Curie point because the dielectric amplifier has greatest gain near this point—that is, the dielectric constant changes the most with unit change in applied control signal. It is possible to select or change the Curie point by choosing materials with various amounts of strontium titanate, barium titanate, etc.

Some materials, such as barium-lead-zirconate, do not depend on variations near the Curie point. These materials, which have a dielectric constant that does not change rapidly with temperature, are more stable. However, they have less gain than Curie-point capacitors.

Circuitry

The dielectric-amplifier circuit is similar to the magnetic-amplifier circuit. The a-c. load current is kept from the control leads by balancing the circuit as in Fig. 9-8; the two

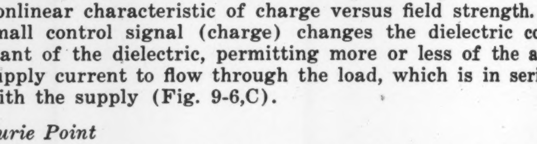
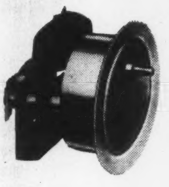


Fig. 9-8. Simplified balanced dielectric-amplifier circuit.



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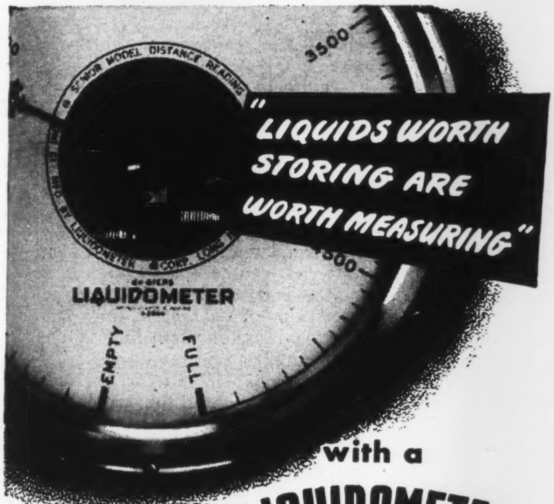

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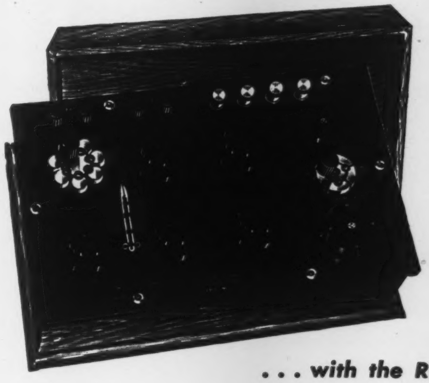

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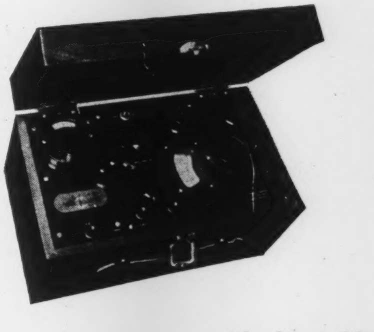

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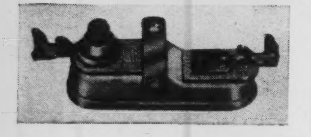

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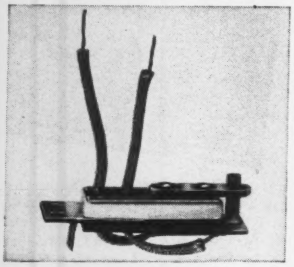

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linear capacitors are necessary to balance the circuit. Rectifiers can be used as in Fig. 9-4 to provide positive or negative feedback.

Features and Applications

The *advantages* of dielectric amplifiers are (1) no moving parts, (2) ruggedness, (3) no filament to burn out, (4) high gain with feedback, (5) compactness and adaptability to shaping, (6) no warm-up time, (7) little controlling power, (8) normally high impedance, (9) cheaper than electron tubes and magnetic amplifiers, (10) frequency range from d.c. to 10 Mc., and (11) power gains up to 10^6 per stage at low frequencies.

The *disadvantages* include (1) frequency limitation around 10 Mc., (2) Curie-point effect, or temperature sensitivity, (3) power-factor losses greater than mica or air dielectric, (4) power dependent on frequency, (5) some dielectrics have aging and time-lag considerations, and (6) requires a high-frequency power supply.

The *applications* include a-c. and d-c. amplifiers, phase shifters, modulators, multivibrators, sweep generators, and filters. The temperature sensitivity of Curie-point dielectrics indicates use as a thermometer.

TRANSISTORS

The *transistor* (Fig. 9-9) is a semiconductor, such as germanium or silicon, with two "cat-whisker" contacts. The device was invented and developed originally at the Bell Telephone Laboratories. Fig. 9-10 shows the symbols and arrangement of electrodes of the transistor. The *base* is a large-area contact to one side of the germanium; the *emitter* and *collector* are thin phosphor-bronze wires that make point contact with the germanium.

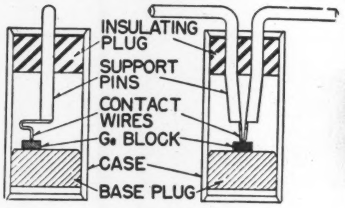

Fig. 9-9. Transistor.

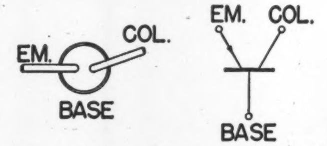

Fig. 9-10. Top view and symbol of transistor.

The principle of operation lies in the fact that the current-voltage relation between a semiconductor and a metallic point contact can be altered by current through a nearby point contact. That is, the resistance of the point contact can be changed by a second point contact in the vicinity of the first contact. The physical explanation involves analysis of how electrons move through a semiconductor. Note that the magnetic amplifier is a variable inductor, the dielectric amplifier is a variable capacitor, and the transistor is a variable resistor. In this respect the transistor is the most like the electron tube.

A typical transistor circuit is shown in Fig. 9-11. The tube is an amplifier because a small change in emitter current (I_1) causes a larger change in collector current (I_2).

The *disadvantages* of transistors include low power-capacity, high noise-level, and frequency-response limitations. The power-handling capacity of transistors is much less than that of either electron tubes or magnetic ampli-

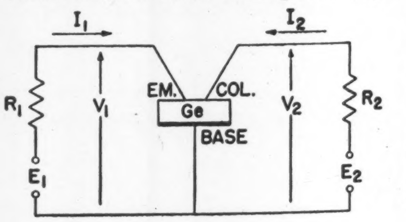

Fig. 9-11. Transistor circuit.

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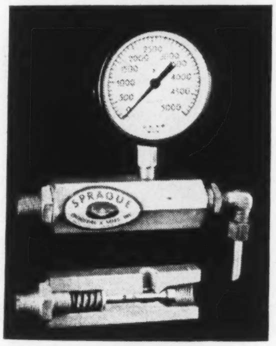

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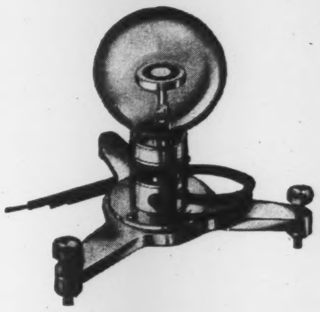

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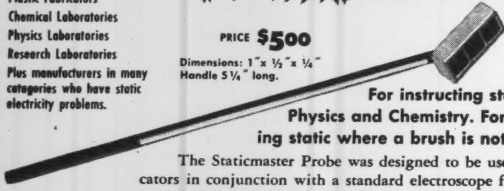

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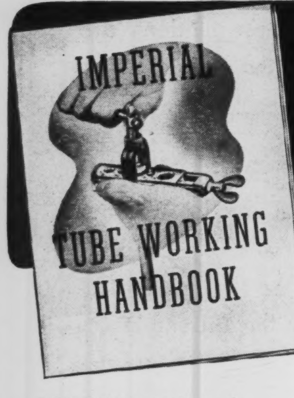

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TEST ITEMS—IX. SOLID-STATE AMPLIFIERS

9-1. Which of the following is NOT a solid-state amplifier?
(a) Magnetic amplifier
(b) Dielectric amplifier
(c) Electron-tube amplifier
(d) Transistor amplifier

9-2 A magnetic amplifier is a variable
(a) resistance
(b) reactance
(c) capacitance
(d) emf.

9-3. The load in a magnetic amplifier is in series with the
(a) control winding
(b) a-c. supply
(c) d-c. signal
(d) all the above

9-4. Maximum current flows through the load in a magnetic amplifier when the
(a) core is saturated
(b) core flux is a minimum
(c) control signal is zero
(d) signal is applied to the load winding

9-5. The magnetic amplifier has two load windings in order to
(a) increase load current
(b) decrease core permeability
(c) cancel load flux in the control leg
(d) cancel load flux in the power legs

9-6. Feedback in the magnetic amplifier is from
(a) load to control leg
(b) load to rectifier bridge
(c) control winding to rectifier bridge
(d) a-c. supply to load

9-7. The core of a magnetic amplifier should have
(a) a rectangular hysteresis loop
(b) low eddy currents
(c) low coercive force
(d) all the above

9-8. When a magnetic amplifier amplifies an a-c. signal, the supply should have a frequency
(a) higher than the signal frequency
(b) lower than the signal frequency
(c) equal to the signal frequency
(d) of zero and be well filtered

9-9. When a flux gate is used to detect and amplify a weak, unidirectional magnetic field, the frequency of the output signal is
(a) zero
(b) the same as the applied a-c. supply
(c) twice that of the applied a-c. supply
(d) many times that of the applied a-c. supply

9-10. The life expectancy of a magnetic-amplifier circuit is limited primarily by the
(a) filament
(b) rectifiers
(c) core
(d) windings

9-11. The time constant of a magnetic amplifier is relatively independent of
(a) power-supply frequency
(b) gain
(c) core material
(d) all the above

9-12. The advantage of using a high-frequency a-c. supply for a magnetic amplifier is
(a) decreased size
(b) decreased time-constant
(c) increased frequency-response
(d) all the above

9-13. A dielectric amplifier differs from a magnetic amplifier in that the former uses
(a) an a-c. supply
(b) a d-c. control signal
(c) change in core permeability
(d) change in dielectric constant

9-14. A dielectric-amplifier capacitor usually has a dielectric material of
(a) ceramic
(b) air
(c) glass
(d) mica

9-15. The characteristic that makes a dielectric amplifier possible is the nonlinear relation between
(a) supply frequency and temperature
(b) temperature and applied charge
(c) dielectric constant and applied charge
(d) dielectric constant and supply frequency

9-16. The Curie point is the
(a) temperature at which dielectric constant is a maximum
(b) supply frequency at which dielectric constant is a maximum
(c) point at which the core saturates most efficiently
(d) feedback at which gain is a maximum

9-17. The transistor differs from the magnetic and dielectric amplifier in that it
(a) is a solid-state device
(b) has no filament
(c) requires no a-c. supply
(d) has no frequency limitations

9-18. Which of the following is NOT an electrode of a transistor?
(a) Base
(b) Emitter
(c) Collector
(d) Plate

9-19. A transitor is a variable
(a) resistor
(b) capacitor
(c) inductor
(d) any of the above

9-20. The transistor electrode that performs the function of the electron-tube control grid is the
(a) base
(b) plate
(c) emitter
(d) collector

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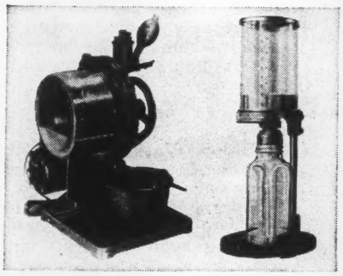

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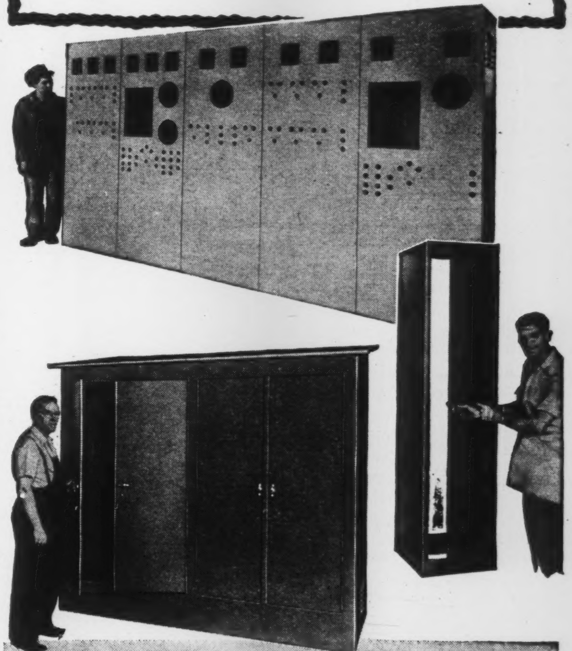

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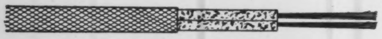

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Manufacturers' New Literature

In this department we report new literature, pertaining to instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 661.

Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

Temperature

U-386 **Temperature Control.** 12-page Catalog G-17 describes maker's full line of expansion-type temperature controllers; includes tables of application and performance data.—The Burling Instrument Co., South Orange, N. J.

U-387 **Thermometer.** 2-page illustrated Bulletin 868 describes simple three-element mercury-filled glass thermometer for temperature measurements in kettles, tanks, etc.—H-B Instrument Co., 2633 Trenton Ave., Phila. 25, Penna.

U-388 **Hand Pyrometer.** 2-page catalog sheet describes "Type FH-1" hand pyrometer for rapid and convenient measurement of surface, liquid, gas, and molten-metal temperatures between 0 and 1500 deg. F.—General Electric Co., Schenectady, N. Y.

U-389 **Controlling Pyrometers.** 4-page Bulletin G-2 illustrates and describes maker's "Sim-Ply-Trol" high-limit, on-off, and alarm relay-type controlling pyrometers for industry.—Assembly Products, Inc., Chagrin Falls 3, Ohio.

U-390 **Temperature Measurements in Central Stations.** (1) 4-page Instrumentation Data Sheet 9.1-11 discusses use of thermocouples and continuous-balance potentiometers; shows basic thermocouples and potentiometers. (2) 4-page Instrumentation Data Sheet 9.1-12 discusses the use of resistance thermometers in steam plants; includes details on d-c. Wheatstone-bridge circuit and continuous-balance recorders.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

U-391 **Heat Treating.** 2-page Instrumentation Data Sheet 5.2-5 discusses the control of high-speed salt baths; describes installation and operation.—Station 40, Brown Instruments Div., Wayne & Windrim Aves., Phila. 44, Penna.

U-392 **High-speed Potentiometer.** 2-page Specification Sheet 179 describes maker's new 2-second response "ElectroniK" 12-inch strip-chart potentiometer.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

Pressure

U-393 **Remote Pressure Recorder.** 2-page Instrumentation Data Sheet 10.2-5 describes a remote pressure recorder comprising the Frederick Flader "Teledyne" unit plus the Brown "ElectroniK" recorder. Operating principles are discussed; transmitter specifications are included.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Philadelphia 44, Pa.

U-394 **Pressure Measurement.** 2-page Folder 25M1251 illustrates and describes pressure-measuring elements and instruments for up to 80,000 psi.—The Foxboro Co., Foxboro, Mass.

Flow

U-395 **Variable-area Flow Meter Handbook.** 40-page illustrated Handbook cover's maker's large line of variable-area meters, tubes, and floats. Includes principles and comparison with variable-head meters; also selection,

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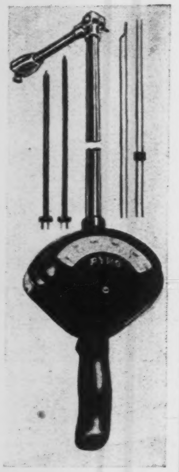

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sizing, and calibration data.—Fischer & Porter Co., Hatboro, Penna.

U-396 **Open-Channel Flow Meter.** Bulletin F-1606 describes application of "Series 500" instruments to measurement of flow of water, sewage, etc., through weirs and flumes of all types. —The Bristol Co., Waterbury 20, Conn.

U-397 **Orifice Plates.** 4-page illustrated Bulletin 54-C describes maker's line of orifice plates. Includes features and ordering information.—Industrial Instrument Corp., Odessa, Texas.

Combustion

U-398 **Combustion Control.** 16-page Bulletin 102-E illustrates and describes maker's air-operated boiler-house controls. Includes fundamental principles of control for various systems.—Bailey Meter Co., 1041 Ivanhoe Rd., Cleveland 10, Ohio.

U-399 **Combustion Indicator.** 2-page Bulletin 801 illustrates and describes photoelectric-relay-type combustion indicator and recorder. Includes features. —Ess Instrument Co., Bergenfield, N. J.

U-400 **Smoke Alarm.** 2-page Bulletin AC-2 describes "Electric Eye" unit guarding against smoke circulated by air-conditioning system. Includes features.—Ess Instrument Co., Bergenfield, N. J.

U-401 **Steam Specialties.** 32-page Catalog No. 50 illustrates and gives detailed specifications of maker's large line of water-level gages, illuminators, try cocks, valves, flow indicators, etc.— Ernst Water Column & Gage Co., Livingston, N. J.

Optical

U-402 **Stereomicroscopes.** 20-page illustrated Catalog D-15,10 describes maker's 14 models of stereomicroscopes with 3-dimensional vision for industry and research.—Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N. Y.

U-403 **Surveying.** 20-page "Surveyor's Notebook" contains unusual surveying problems and solutions; also illustrated descriptions of many surveying instruments.—W. & L. E. Gurley, Troy, N. Y.

U-404 **Borescope.** 4-page March 1952 issue of "Engelhard Industries News-letter" contains articles on a new borescope, tri-metal shims, improved UV meter, silver brazing, and inserted electrical contacts.—Charles Engelhard, Inc., 850 Passaic Ave., East Newark, N. J.

U-405 **Photocopy.** 4-page illustrated Bulletin F1151 describes a new 60-second copying device and Polaroid-Land camera. Includes features and specifications.—Polaroid Corp., Dept. CM, Cambridge 39, Mass.

U-406 **Illuminated Magnifier.** 2-page catalog sheet describes new fluorescent illuminator, with 2- or 4-power lens, for laboratories and inspection.—Stocker & Yale, Marblehead, Mass.

Process Control

U-407 **Industrial Instrumentation.** 128-page book entitled "Fundamentals of Instrumentation for the Industries" comprises (1) preface, (2) fundamentals of measurement and control, (3) measurement of process variables, (4) remote transmission of measurements, (5) types of automatic controllers, (6) power units and final control elements, (7) control systems, (8) panelboards, (9) typical applications.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

U-408 **Process Control.** 16-page Condensed General Catalog 52 illustrates and describes maker's large line of controllers—valves, positioners, and process controllers for pressure, temperature, and liquid level. Includes features, ranges, and ratings.—Mason-Neilan Regulator Co., 1190 Adam St., Boston 24, Mass.

U-409 **Control Panel.** 4-page Instruction No. 2011 illustrates and describes maker's "Manual Control Panel" for switching between automatic, manual, test, and service modes of control with new Model 60,000 series process controllers. Includes features, operation, and specifications.—Mason-Neilan Regulator Co., 1190 Adams St., Boston 24, Mass.

U-410 **Plant and Lab Instrumentation.** 36-page Bulletin P-1245 describes line of "Dynamaster" instruments for industrial plant, pilot plant, process, research and laboratory use; describes a number of new electronic instruments for recording and controlling temperature, pH, speed, voltage, power, current, smoke density, thickness, strain, etc.—The Bristol Co., Waterbury 20, Conn.

U-411 **Plant and Lab Instrumentation.** 8-page Vol. 11 No. 4 issue of "Modern Precision" contains sixteen articles describing newest uses of instruments in industries, power plants, and laboratories.—Leeds & Northrup Co., 4907 Stenton Ave., Phila. 44, Penna.

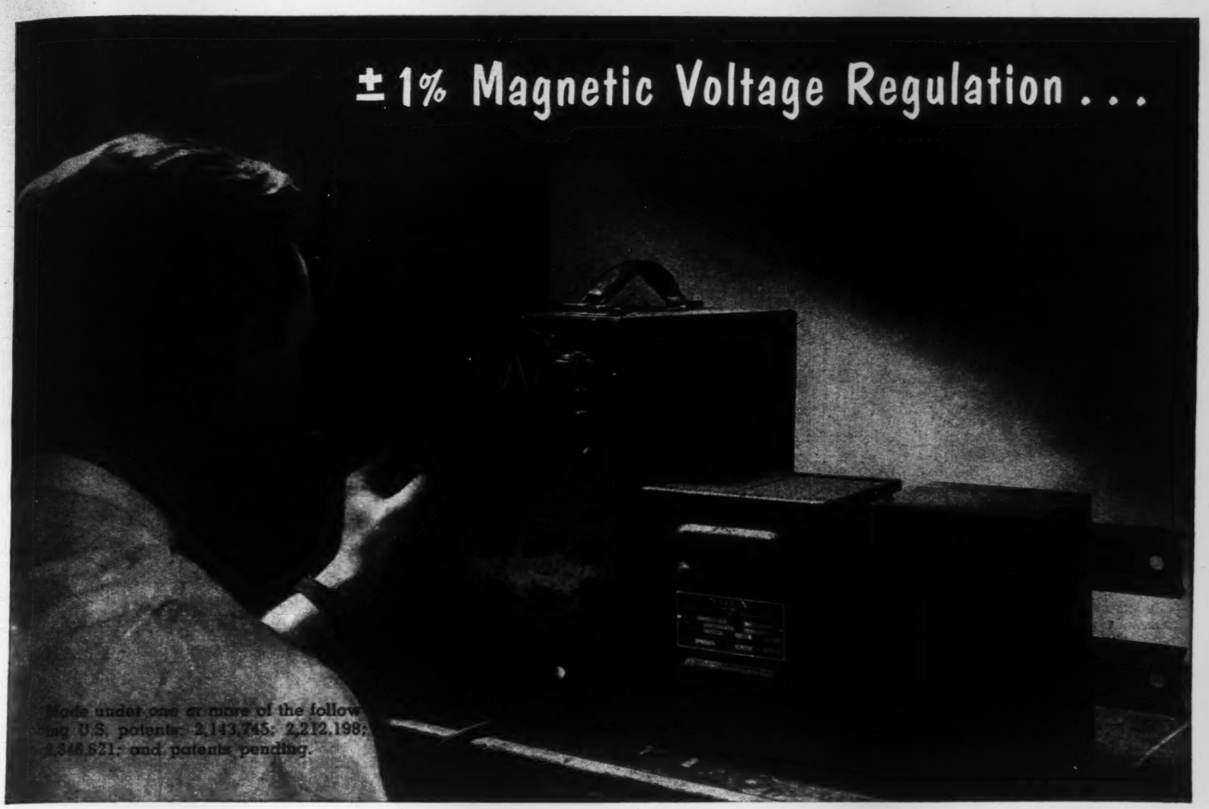
U-412 **Centralized Instrumentation.** 32-page illustrated Bulletin 85-20 describes conventional and graphic panelboards and instruments utilized. Includes latest-type panelboards and typical control systems.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

U-413 **Compressor-station Instrumentation.** 4-page Instrumentation Data Sheet 7.2-3 reviews instrument applications in gas compressor stations for automatic operation, minimal maintenance, and maximum protection.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

U-414 **Circuit Controller.** 12-page Engineering Bulletin 505 describes "Regohm" direct-acting, finger-type voltage, frequency, and current regulators. Includes typical circuits and use in servosystems.—Electric Regulator Corp., 50 Day St., S. Norwalk, Conn.

U-415 **Process Instrumentation.** 40-page Vol. 5 No. 6 issue of "Instrumentation" features articles on temper-

± 1% Magnetic Voltage Regulation . . .



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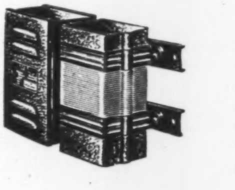

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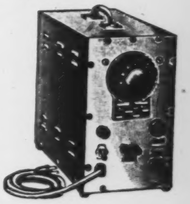

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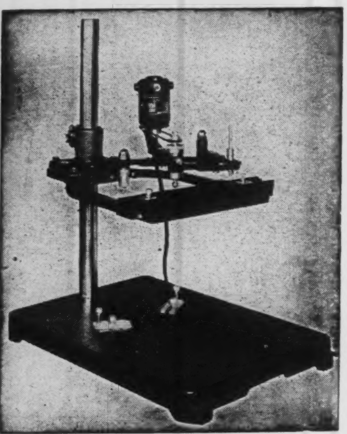

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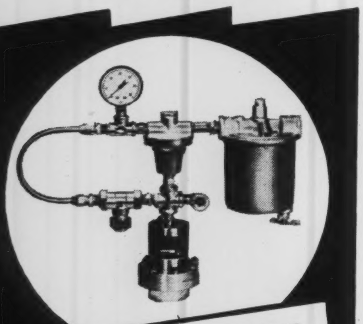

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ature test chambers, strip-mill measurements, brake design, brick production, hygrometers, new pressure pilot, and others.—Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Phila. 44, Penna.

U-416 **Air-operated Current-controller.** 2-page Instrumentation Data Sheet 11.3-2a describes temperature control of electrically-heated equipment with Conoflow unit plus Brown "Air-O-Line" control.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

U-417 **Miniature Indicators.** 4-page Specification Sheet 770 describes operation of "Tel-O-Set" miniature indicating pneumatic receiver that provides manual loading and remote index setting; also typical control system.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.

Radioactivity

U-418 **Nucleonic Instruments.** 34-page catalog contains illustrated brochures on large line of "EKCO" British-made nucleonic equipment—amplifiers, scales, monitors, oscillograph, counter, thickness gage, counter tubes, etc.—The American Tradair Corp., Chrysler Bldg., 405, Lexington Ave., New York 17, N. Y.

U-419 **Radiation Counter Tubes.** 26-page illustrated catalog describes maker's line of permanent-sensitivity counter tubes for alpha, beta, gamma, and X-ray applications. Includes features and operation.—Amperex Electronic Corp., Hicksville, L. I., N. Y.

U-420 **Neutron Counter.** Specification sheet and reprint of a 6-page article provide theory and details of "Model F-1 Raychronix" fast-neutron counter.—Radioactive Products, Inc., 443 West Congress, Detroit 26, Michigan.

Chemical Laboratory

U-421 **Laboratory Apparatus.** 32-page Vol. 21 No. 4 issue of "The Laboratory" features articles on a new Titrimeter, the first permanently-marked thermometers ever produced, a self-zeroing burette, photomultiplier attachment for spectrophotometer and other new items.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.

U-422 **Laboratory Apparatus.** 16-page No. 9 issue of "Laboratory Spotlight" features illustrated description of "Beckman" infrared spectrophotometer, "Saybolt" viscosimeter, distillation apparatus, and new "Labline" furniture.—Harshaw Scientific Co., Cleveland 6, Ohio.

U-423 **Laboratory Apparatus.** 8-page Vol. 4 No. 1 issue of "Lanco Apparatus News" describes new Kinney vacuum pump, electric stopwatches, aluminum speed desiccators, filmamatic automatic pipetting machine, air-velocity meters, and others.—Arthur S. LaPine & Co., 6001 S. Knox Ave., Chicago 10, Ill.

U-424 **Analytical Balances.** 12-page Bulletin 515 is catalog of "SeKo" analytical balances, from students' models to laboratory types.—Seederer-Kohlbusch, Englewood, N. J.

U-425 **Analytical Balances.** 32-page Vol. 2 No. 2 issue of "Physics and Chemistry Digest" contains digests of technical-classroom articles and experiments, and illustrated descriptions of maker's balances and laboratory apparatus.—W. M. Welch Scientific Co., 1515 Sedgwick St., Chicago 10, Ill.

U-426 **Projection Analytical Balances.** 8-page folder illustrates and describes line of "Original Sartorius" German-made analytical balances with projection indication.—Sartorius Div., C. A. Brinkmann & Co., P. O. Box 532, Great Neck, N. Y.

U-427 **Induction Furnaces.** 12-page catalog illustrates and describes "Leco" furnaces for carbon and sulphur analyses, etc.; contains technical directions. —Laboratory Equipment Corp., St. Joseph, Mich.

U-428 **Kovar-glass Seals.** 16-page illustrated Bulletin 851 contains complete specifications on maker's large line of Kovar-to-glass-sealed terminals, lead-ins, and stand-offs.—Stupakoff Ceramic & Mfg. Co., Latrobe, Penna.

U-429 **Markers and Signs.** 50-page illustrated Catalog 170 covers maker's large line of self-sticking markers, signs, stencils, and printed roll tapes.—W. H. Brady Co., Dept. 248, 1630 E. Spring St., Chippewa Falls, Wis.

Chemical Process

U-430 **Mass Spectrometer.** 12-page Vol. 6 No. 1 issue of "CEC Recordings" features articles on mass-spectrometer design and use, stress analysis, air pollution, and new recording lamp.—Consolidated Engineering Corp., 300 N. Sierra Madre Villa, Pasadena 8, Calif.

U-431 **Infrared Analyzer.** 8-page Bulletin 36 covers principles, features, applications, and plant requirements for infrared absorption analysis of continuous processes.—Baird Associates, Inc., 33 University Rd., Cambridge 38, Mass.

U-432 **Analytical Instruments.** 12-page Vol. 3 No. 1 issue of "Better Analysis" features article on use of direct-reading emission spectrometer in production control of copper-base alloys. Other articles cover gas analyzers and flame photometry.—Baird Associates, Inc., 33 University Rd., Cambridge 38, Mass.

U-433 **Infrared Analysis.** 8-page booklet "Product Control Through Infrared Analysis" tells how six chemical manufacturers have applied infrared analysis to product-control problems.—The Perkin-Elmer Corp, Norwalk, Conn.

Valves and Tubing

U-434 **Control Valves.** 48-page illustrated Catalog 51 describes maker's large line of straight way, 3-way, and 4-way poppet-type control valves. Includes features, operation, and diagrams for operation by solenoid, hand, foot, pilot valves, and sequence valves. —Ross Operating Valve Co., Detroit 3, Mich.

U-435 **Needle Valves.** 24-page general catalog describes maker's line of forged and bar-stock needle valves, pet cocks, gage glasses, etc.—Dragon Engineering Co., 5817 S. Central Ave., Los Angeles 11, Calif.

U-436 **Protection for Air and Hydraulic Tubing.** 4-page Bulletin BA-927 describes new "Armortube" containing four, eight, or twelve aluminum or copper tubes.—Bailey Meter Co., 1050 Ivanhoe Road, Cleveland 10, Ohio.

U-437 **Packing Glands.** 2-page bulletin 1251 illustrates and describes new packing glands for introducing tubes and rods into pressure systems. Includes features and specifications.—Conax Corp., 4515 Main St., Buffalo 21, N. Y.

Testing

U-438 **Thickness Gage.** 34-page catalog contains brochure on "EKCO" British-made radioactivity thickness gage plus large line of other nucleonic instruments.—The American Tradair Corp., Chrysler Bldg., 405, Lexington Ave., New York 17, N. Y.

U-439 **Stress-analysis.** 4-page Bulletin 5 describes Models "BA-2" and "BA-12" bridge amplifiers and new Model "BS-6" switch and balance unit for prebalancing each gage setup in multichannel strain-gage installations. —Ellis Associates, Box 77, Pelham, N. Y.

U-440 **Spring Tester.** 4-page bulletin describes new air-operated production-line model of spring tester with large "go and no-go" gage and features for rapid operation.—Link Engineering Co., 13843 Elmira Ave., Detroit 27, Mich.

Production Counters

U-441 **Production Counters.** 66-page Catalog 52 illustrates and describes large line of mechanical counters, electric counters, counter-actuating switches, coil-winding counters, time totalizers, and count-markers. Includes features and applications in various industries.—Production Instrument Co., 710 W. Jackson Blvd., Chicago 6, Ill.

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U-442 **Accelerometer.** 2-page Technical Data Sheets 8.0 and 8.1 give specifications and features of maker's "Type GL-H" accelerometer.—Genisco, Inc., Los Angeles, Calif.

U-443 **Vibration Mounts.** 4-page Catalog MB-110 covers maker's vibration

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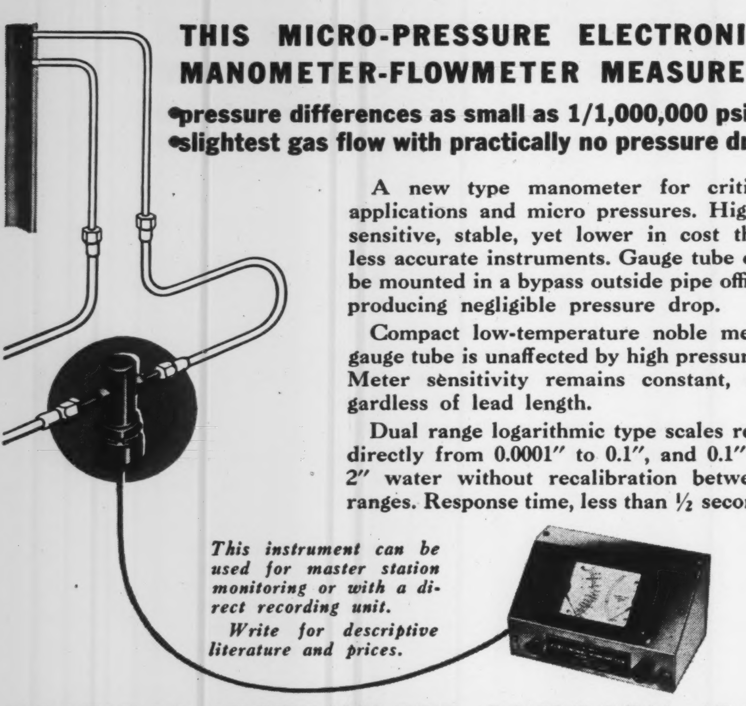

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U-444 **Tachometers.** 2-page Technical Data Sheet 42HJK illustrates and describes "Type 42" tachometer indicators with ¼-percent accuracy for 36 to 100,000 rpm.—Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.

U-445 **Frequency Measurements.** 4-page Vol. 8 No. 1 issue of "Biddle Instrument News" describes "Frahm" resonant-reed frequency meters for indicating motion frequencies from 15 to 15000 cps.—James G. Biddle Co., 1316 Arch St., Phila. 7, Penna.

Electrical and Electronic Instruments

U-446 **Distended-scale VTVM.** 4-page bulletin illustrates and describes new distended-scale VTVM for accurate measurement of a-c. and d-c. millivolts, volts, ohms, and megohms. Includes features and block diagram.—Southwestern Industrial Electronics Co., 2831 Post Oak Rd., Houston 19, Texas.

U-447 **Test Instruments.** 24-page pocket-size condensed catalog describes British-made "Avometer" line of a-c./d-c. meters, universal tube testers, signal generators, industrial test sets, bridges, and accessories.—British Industries Corp., 164 Duane St., New York 13, N. Y.

U-448 **Test Instruments.** 4-page Vol. 8 No. 1 issue of "Allied News" features articles on TV tower, binaural sound, power supply, and VTVM.—Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill.

U-449 **Test Instruments.** 8-page Catalog 51-1 describes portable line of tube testers, circuit analyzers, multirange instruments, synchro-sweep generator and signal generator.—Oak Ridge Products, 37-01 Vernon Blvd., L. I. 1, N. Y.

U-450 **UHF Test Instruments.** 4-page illustrated bulletins describe maker's UHF oscilloscope and precision frequency meter.—Lavoie Laboratories, Inc., Matawan-Freehold Rd., Morganville, N. J.

U-451 **Signal Generator.** 2-page Form 680-1051 describes "Model 680" r-f. marker and crystal calibrator for solving TV front-end problems.—The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland 8, Ohio.

U-452 **Dual-beam Oscilloscope.** 2-page brochure illustrates and describes new moderate-priced dual-beam oscilloscope. Includes features and specifications.—Allen B. Du Mont Laboratories, Inc., 1500 Main Ave., Clifton, N. J.

U-453 **Oscillographs.** 2-page illustrated Forms 802, 805, 806, and 807 describe maker's ink-writing oscillograph elements, research amplifier, d-c. amplifier, and magnetic oscillographs.—Edin Co., Worcester 8, Mass.

U-454 **Volt-ampere-wattmeter.** 4-page bulletin describes new "Model 101 VAW Meter" which gives direct readings of voltage, current, and power between 20 and 200,000 cps.—John Fluke Engineering Co., Box 755Y, Springdale, Conn.

U-455 **X-Y Recorder.** Data sheet illustrates and describes new "Autograf" general-purpose recorder with two independent servo-actuated recording axes. Includes features and applications.—Francis L. Moseley, 1136 N. Las Palmas Ave., Los Angeles 38, Calif.

U-456 **Galvanometers and Dynamometers.** 20-page Catalog Section ED covers basic features and specifications of maker's d-c. and a-c. galvanometers of the pointer or reflecting type; also low-level d-c. indicating amplifiers, direct-reading instruments, and recorder pre-amplifiers. Includes a galvanometer selector guide.—Leeds & Northrup Co., 4934 Stenton Ave., Phila. 44, Penna.

U-457 **Magnetic Recording.** 8-page March issue of "Brush Strokes" features article on "Trends and Developments in Magnetic Recording Heads."—The Brush Development Co., 3322 Perkins Ave., Cleveland, Ohio.

U-458 **Magnetic Recording.** 4-page illustrated Bulletin 15-M covers maker's line of magnetic recording components —play-back head, recording head, erasing head, degausser, and erasing pencil. —Cinema Engineering Co., 1510 W. Verdugo Ave., Burbank, Calif.

U-459 **Tape Recorder.** 2-page illustrated brochure describes features of new "MagneCordette" tape recorder and accessories.—Allied Radio, 833 W. Jackson Blvd., Chicago 7, Ill.

U-460 **Regulated Adjustable Power-supplies.** 4-page illustrated Bulletin V1051 describes maker's "Varicell" stabilized-regulated adjustable power supplies for low-voltage d.c. principle and features.—The Superior Electric Co., Bristol, Conn.

U-461 **Frequency Measurement.** 4-page Vol. 3 No. 5-6 issue of "hp Journal" features article on microwave frequency measurements and VSWR measurements.—The Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

U-462 **Laboratory Amplifiers.** 2-page leaflet describes "Research Amplifier" for recording biological potentials and 3-stage d-c. amplifier with gain of about 10,000.—Edin Co., Inc., Worcester 8, Mass.

U-463 **Ground Resistance Measurement.** 2-page leaflet describes seven models of maker's "Vibroground" instruments for all ground resistance tests.—Associated Research, 3758 W. Belmont Ave., Chicago 18, Ill.

U-464 **Sound-level Meter.** 8-page March 1952 issue of "The General Radio Experimenter" contains technical description of a new basic instrument for sound and noise measurements.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-465 **Carrier Communication.** 12-page Vol. 1 No. 1 issue of "The Lenkurt Demodulator" features a 6-page basic article on wave filters. Future issues will contain articles on principles and applications of carrier equipment.—Publications Dep't, Lenkurt Electric Co., San Carlos, Calif.

U-466 **Winding Tester.** Specification sheet describes new "PMD-W" for de-

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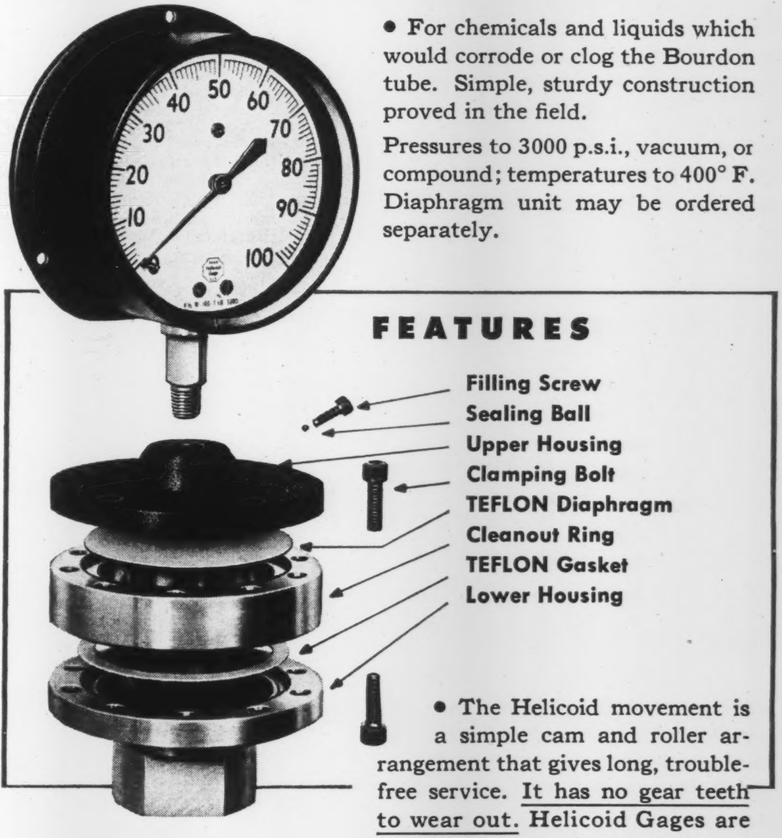

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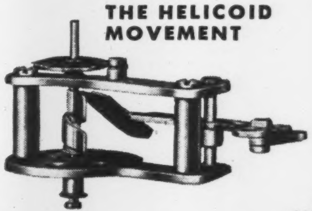

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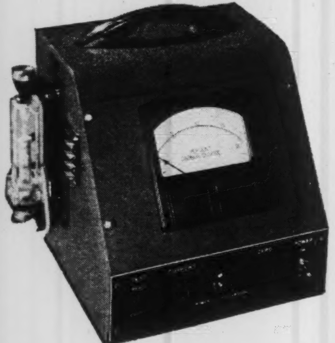

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U-467 **Bin-level Indicators.** 20-page 1952 catalog illustrates and describes maker's large line of "Bin-Dicator" pressure-switch-type bin-level indicators and "Bin-Flo Aerator Units."—The Bin-Dicator Co., 13946-201 Kercheval, Detroit 15, Mich.

Electrical and Electronic Components

U-468 **Miniature Power Resistors.** 2-page Bulletins R-14 and R-12 illustrate and describe maker's new 25- and 50-watt miniature precision "Dalohm" silicone-coated resistors. Includes features and specifications.—Dale Products, Inc., Columbus, Neb.

U-469 **Negative-coefficient Resistors.** 8-page Bulletin 13 illustrates and describes maker's line of "NTC" resistance units with large, negative temperature-coefficients. Includes properties and application data.—Keystone Carbon Co., St. Marys, Penna.

U-470 **Negative-coefficient Resistors.** 2-page Bulletin 249 A gives characteristics and suggested uses for maker's line of resistors with negative temperature-coefficients.—Stupakoff Ceramic & Mfg. Co., Latrobe, Penna.

U-471 **Rheostats and Resistors.** 2-page February issue of "Ohmite News" illustrates and describes features of taper-wound rheostats and tapped resistors.—Ohmite Mfg. Co., 4835 Flournoy St., Chicago 44, Ill.

U-472 **Rheostats and Resistors.** 2-page March issue of "Ohmite News" features article on rheostats with rating from 25 to 1000 watts, 1-percent precision resistors, and other electrical products.—Ohmite Mfg. Co., 4835 Flournoy St., Chicago 44, Ill.

U-473 **Rheostats, Switches and Pots.** 8-page Bulletin No. 177 describes maker's complete line of wire-wound "pots," wire-wound rheostats, and slide switches. Contains dimensions and specifications.—Wirt Co., 5221 Greene St., Phila. 44, Penna.

U-474 **Capacitors.** 20-page Vol. 17 No. 2 issue of "CD Capacitor" features article on signal tracing and description of some of maker's capacitors.—Cornell-Dubilier Electric Corp., Hamilton Blvd., S. Plainfield, N. J.

U-475 **Mercury Batteries, Capacitors, etc.** 12-page Product Index contains condensed descriptions of maker's line of batteries, capacitors, contacts, rectifiers, resistors, switches, vibrators, metals and ceramics, tuners, and resistance-welding supplies.—P. R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis 6, Ind.

U-476 **Ceramic Trimmers.** 2-page issue No. 604 of "Engineering Bulletin" illustrates and describes maker's "Type AO8" ceramic trimmer capacitors. Includes features and performance.—Herlec Corp., 422 N. 5th St., Milwaukee 3, Wis.

U-477 **Variable Transformer.** 4-page Bulletin P252 gives detailed description of new small-size "Type 10 Powerstat" voltage control for equipment consuming 50, 100 or 150 watts.—Superior Electric Co., Bristol, Conn.

U-478 **Transformers and Coils.** 16-page Catalog 5211 contains indexed description of maker's large line of transformers and coils—driver, input, interstage, output, power, vibration, etc.—Merit Coil & Transformer Corp., 4427 N. Clark St., Chicago 40, Ill.

U-479 **Connectors.** 4-page Vol. 5 No. 2 issue of "Amphenol Engineering News" features articles on use of maker's connectors in missiles, cameras, and instruments.—American Phenolic Corp., 1830 S. 54th Ave., Chicago 50, Ill.

U-480 **Connectors.** 6-page folder illustrates and describes maker's large line of rack-and-panel, standoff, and cable connectors; also terminal blocks. Includes features and specifications.—Continental Connector Corp., 45-01 Northern Blvd., L. I. 1, N. Y.

U-481 **Grounding Sheath Connectors.** 4-page "Sheet 55" describes new two-piece compression-type connectors for terminating braided shields.—Thomas & Betts Co., Elizabeth 1, N. J.

U-482 **Instrument Switches.** 4-page illustrated Catalog 17-S describes features of maker's instrument-type rotary tap switches.—Cinema Engineering Co., 1510 W. Verdugo Blvd., Burbank, Calif.

U-483 **Snap-action Switches.** 2-page Data Sheet 63 illustrates and describes maker's "make-before-break" snap-action switch, catalog listing "BZ-2G." Includes features and operation.—Micro Switch, Freeport, Ill.

U-484 **Pyrometric Switches.** 12-page Catalog 5800 illustrates and describes rotary, key, and plug-type pyrometric switches; gives applications and pertinent circuits.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Phila. 44, Penna.

U-485 **Pilot Lights.** 200-page Handbook of Pilot Lights, Form L-149, has actual-size illustrations and complete specification on maker's large line of pilot lights for every service. Includes selection and application data.—The Dial Light Co. of America, 900 Broadway, New York 3, N. Y.

U-486 **Servo Stabilizer.** 4-page illustrated brochure describes maker's "Twin-T" filter, phase changer, peaked amplifier, and servosystem stabilizer. Includes principle and operation.—Kalbfell Laboratories, Inc., P. O. Box 1578, San Diego 10, Calif.

U-487 **Loudspeakers.** 28-page "Technilog" covers maker's large line of loudspeakers, drivers, and projectors. Includes technical data on selection, matching, controlling volume, reverberation, baffling, etc.—University Loudspeakers, Inc., 80 S. Kensico Ave., White Plains, N. Y.

U-488 **Computer Components.** 16-page brochure illustrates and describes maker's line of unitized pulse-control equipment, including pulse generators, flip-flops, coincidence detectors, gaters, delays, etc.—Control Instrument Co., Inc., 67 35th St., Brooklyn 32, N. Y.

U-489 **Printed Circuits.** 4-page Bulletin 1151 illustrates and describes maker's line of printed-circuit units, including integrators, interstage coupling, and other circuit combinations.—Stupakoff Ceramic & Mfg. Co., Latrobe, Penna.

U-490 **Time-delay Circuits.** 20-page Vol. 17, No. 3, March 1952 issue of the "CD Capacitor" features 6-page article on time-delay circuits.—Cornell-Dubilier Electric Corp., Hamilton Blvd., S. Plainfield, N. J.

U-491 **Coaxial Cable.** 2-page bulletin describes "Flexit" super-flexible coaxial cable which simplifies installations.—Columbia Technical Corp., 5 E. 57th St., New York 22, N. Y.

Shop Equipment

U-492 **Soldering Iron.** 6-page bulletin GED-1583 describes new G-E lightweight 60-watt soldering iron for pinpoint soldering.—General Electric Co., Schenectady 5, N. Y.

U-493 **Instrument Mercury.** 2-page illustrated Form IM describes maker's instrument mercury in polyethylene bottles.—Bethlehem Apparatus Co., Inc., Front and Depot Sts., Hellertown, Penna.

BOOK REVIEWS

Materials Technology for Electron Tubes

By Walter H. Kohl

494+ xv pages, well illustrated; published by Reinhold Publishing Co., 330 W. 42nd St., New York, N. Y., 1951; $10.00.

This is the first comprehensive English-language text on the subject of the materials and techniques of electron-tube construction. The author, who is consultant for Collins Radio Co., Cedar Rapids, Iowa, covers the metallurgy, characteristics, and reactions of glass, ceramics, mica, tungsten, molybdenum, tantalum, copper, nickel, and graphite. The author uses an extensive bibliography of the work done by researchers throughout the world. Seals, atomic theory, crystal classification, and electron emission are included. The emphasis is on practical factors. The style and level are suited for professional and nonprofessional personnel.

TV and Electronics as a Career

By Ira Kamen and Richard H. Dorf

326 pages, 136 illustrations, cloth; published by John F. Rider Publisher, Inc., 480 Canal St., New York 13, N. Y.; $4.95.

The radio, TV, and servicing field is reviewed by the authors and three contributing authors—W. H. Bohlke, RCA Service Co., Inc.; R. W. Peterson, Admiral Corp.; and J. R. Poppele, WOR-TV. The types of people employed, and the type of background required for employment, are discussed. The fields covered include TV broadcasting, AM-FM broadcasting, radio and TV manufacturing, electronic engineering, TV servicing, receiver and component distribution, and armed-force electronics. Several biographies of outstanding men and a list of schools and colleges teaching radio, TV, and electronics are included.

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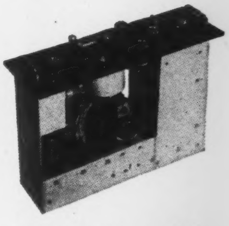

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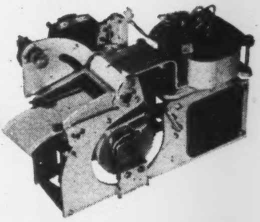

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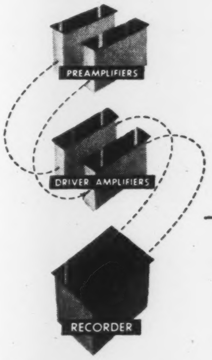
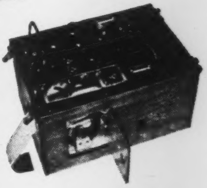


Any of the recording channels in the three systems at the right may include *either* a Strain Gage or General Purpose Amplifier, or the latter in combination (in 2-, and 4-channel systems) with either AC or DC Preamplifiers. For, any of the Amplifiers or Preamplifiers provided for in a system may be quickly *removed* from its place in the system and as quickly *replaced* with an alternate type.



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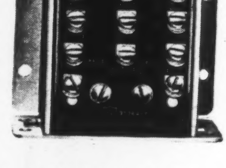

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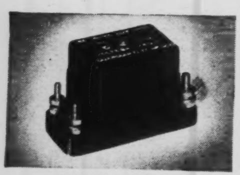

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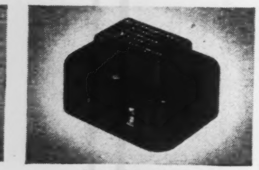

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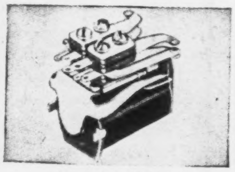

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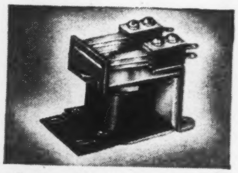

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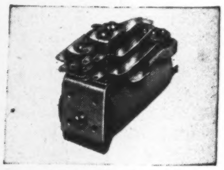

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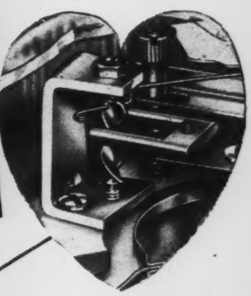

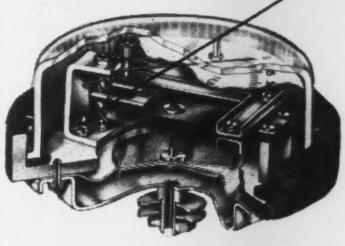

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